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THE NATURE OF EARLY-SEASON INFERTILITY IN SHEEP [1]

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MANY producers of spring lambs have found it difficult to get their ewes settled uniformly early in the breeding season. As a result, labor and management problems are greatly increased and the price advantage of early spring lambs is lost. In order to realize the important advantages of an early, uniform lamb crop, it becomes necessary to improve the breeding efficiency of the flock in the early part of the breeding season. A knowledge of the factors affecting early-season fertility, therefore, is of utmost importance.

The records of the University of Wisconsin Hampshire and Shropshire flocks for 6 years were analyzed to determine the variation throughout the breeding season and among the different breeding seasons. In addition an experiment was run in 1952 to estimate the percentage of early-season infertility in the flock which was due to failure of fertilization and that which was due to embryonic death. The association between fertility and semen quality was also studied.

Six-Year Flock Record

Materials and Methods

This study included the records for the years 1947 through 1952, inclusive, and covered 303 Hampshire and 223 Shropshire ewe-years. Breeding and lambing dates were kept for all of these and the dates of the first heat observed after July 31 were recorded for each year except 1949 (225 Hampshire and 182 Shropshire ewe-seasons.) From these records the percentage of ewes of each breed showing first heat (not necessarily the first heat of the year, but the first heat of each ewe after July 31) during each two-week interval through October for the five indicated years, was determined.

The percentage of fertile ewes (service resulting in 18-day non-return to heat) from first services over the whole breeding season for each year and the percentage of fertile ewes from first services for each two-week interval from August 1 through October over the six years were determined for each breed.

[1] Paper from the Department of Genetics (No. 602) and the Department of Animal Husbandry. Published with the approval of Director of the Agricultural Experiment Station. Supported in part by the Research Committee of the Graduate School from funds supplied by the Wis. Alum. Res. Foundation.

Results and Discussion

Early-Season Estrus. Only 7% of the Shropshire ewes came into heat during the first two weeks of August (table 1) as compared with 45% of the Hampshires. Further, only 26% of the Shropshire showed heat during the month of August as compared to 79% of the Hampshires. The majority of the Shropshires, 68% exhibited their first heat in September, after the majority of the Hampshires already had been

TABLE 1. FIRST HEAT PERIOD OF THE BREEDING SEASON [a] (FIVE-YEAR STUDY)

Breed	Shropshire	Hampshire
Number ewe seasons	182	225
% showing first heat during:		
August 1–15	7	45
August 16–31	19	34
September 1–15	49	14
September 16–30	19	3
After September 30	6	4

[a] This may not be the first heat, but first observed heat after July 31.

in heat. This difference was highly significant statistically and is considered a hereditary breed difference. McKenzie and Phillips (1930), Cole and Miller (1935), Hafez (1952), de Baca *et al.* (1954) and others have observed breed differences in the onset of the breeding season.

Fertility. The lowest percentages of fertility from first service were in 1947, 1951, and 1952 with 27%, 40% and 35%, respectively for the Shropshires and 34%, 37% and 28% for the Hampshires (tables 2 and 3). These may be compared with the higher ($P<0.01$) fertility percentages, 58%, 76% and 50% for the Shropshires and 67%, 62% and 58% for the Hampshires for 1948, 1949 and 1950. Breeding was begun the first of August in the years of lower average fertility; whereas in the years which show the higher percentages of fertility for both breeds, breeding was delayed until the first of September.

A comparison (tables 2 and 3) of the percentages of first-service ewes settling during successive two-week intervals (based on a six-year average) shows that the percentage of fertility in the Shropshires was lowest in August with 0% and 17% respectively for the two periods. It increased to a peak of 60% during the last two weeks in September and then fell off to 46% for October. The Hampshires likewise were lowest in fertility during August with 30% and 26% respectively.

TABLE 2. HAMPSHIRE EWES—FERTILITY ON FIRST SERVICE (18-DAY NON-RETURNS)

Year	Interval of first service										% Non-return over all intervals
	Aug. 1–15		Aug. 16–31		Sept. 1–15		Sept. 16–30		Oct. 1–25		
	No. bred	No. N.R.	No. bred	No. N.R.	No. bred	No. N.R.	No. Bred	No. N.R.	No. Bred	No. N.R.	
1947[a]	27	11	11	2	1	0	1	1	1	0	34
1948[b]					39	24	6	6			67
1949[b]					31	18	6	5			62
1950[b]					26	15	6	3	1	1	58
1951[a]	16	2	12	3	12	8	7	4	4	2	37
1952[a]	11	3	31	9	3	0			1	1	28
% Non-return over all years	30		26		58		73		57		

[a] Breeding begun Aug. 1.
[b] Breeding begun Sept. 1.

TABLE 3. SHROPSHIRE EWES—FERTILITY ON FIRST SERVICE (18-DAY NON-RETURNS)

Year	Interval of first service										% Non-return over all intervals
	Aug. 1–15		Aug. 16–31		Sept. 1–15		Sept. 16–30		Oct. 1–25		
	No. bred	No. N.R.	No. bred	No. N.R.	No. bred	No. N.R.	No. Bred	No. N.R.	No. Bred	No. N.R.	
1947[a]	4	0	20	4	9	3	4	3	4	1	27
1948[b]					31	18	7	5	5	2	58
1949[b]					24	18	5	4			76
1950[b]					19	9	8	4	1	1	50
1951[a]					5	3	3	0	2	1	40
1952[a]					25	9	3	2	1	1	35
% Non-return over all years	0		17		53		60		46		

[a] Breeding begun Aug. 1.
[b] Breeding begun Sept. 1.

The fertility increased to a peak of 73% for the last two weeks in September and then fell off again to 57% during October. This change in the percentage of first service fertility in each breed with the advance of the season was highly significant statistically. The same comparisons made for return services (data not included) indicate similar trends in fertility with the differences being statistically significant for the Shropshires and highly significant for the Hampshires. (Incidentally a comparison of the percentages of the Hampshire flock settling by October 1 did not show an advantage for the years when breeding was begun August 1 over those in which it was begun September 1. The same was also true of percentage lamb crop for breedings up to October 1).

Experimental Study

Materials and Methods

The 1952 University of Wisconsin flock of 52 Hampshire and 34 Shropshire ewes and three stud rams (one Hampshire and two Shropshire) together with 92 aged, western ewes were used for the study.

The rams were kept in individual pens adjacent to each other and were trained to serve an artificial vagina. At least one semen collection per ram was made each week and was evaluated according to the following tests:

(1) Volume—milliliters semen per ejaculate.

(2) Initial motility—mass movement and estimated percentage of sperm showing forward motion when diluted approximately 20 to 1 with a modified Krebs-Ringer solution.

(3) Concentration per mm^3 as determined by hemocytometer count.

(4) Methylene blue reduction-time modified for use in ram semen evaluations.

During the first week in August 1952, the western test ewes were identified and placed on a blue-grass pasture adjacent to those pastures occupied by the various purebred flocks. Vasectomized rams whose briskets had been painted were turned with each group of ewes. All flocks were checked for heat twice daily. If any ewe was painted by the teaser rams she was separated from the flock and checked to determine whether she would stand for a ram to mount her. If she stood she was considered in heat and was bred once approximately 12 hours later.

All purebred ewes which did not settle were rebred at subsequent heats up to November 2.

The western ewes were assigned, as they came into heat, to the various stud rams roughly in proportion to the number of purebred flock ewes being bred to each of them at the same time in order to get fertilization information contemporaneous with the flock breeding.

Most of the breeding was done by hand-mating except that artificial insemination was used for approximately two weeks at the beginning of the season and on a few other instances when it was not possible to get natural matings. When artificial insemination was used the semen was collected by means of the artificial vagina and used either without dilution or diluted one part semen to four parts modified Krebs-Ringer solution and inseminated at the rate of .2 ml. per insemination. It appeared from a summarization of results that the fertility from artificial insemination probably was not different from that obtained by natural service, therefore, all results were pooled.

The western ewes were slaughtered two to three days after insemination or mating. The ova were recovered and observed under low and high-power magnification for evidences of normality and fertilization. Observations were also made to determine the normality of the reproductive tract.

Results and Discussion

Test Ewes

Ova Recovered. Ova were recovered from 77 of the 92 western test ewes slaughtered two to three days after breeding. As it was impossible to know the condition of the ova which were not recovered, the assumption has been made that they did not differ on the average from those recovered.

All calculations have been made on a per-ewe basis to make possible direct comparisons with the flock ewes.

Fertilization Failure. There was fertilization failure of all ova in 27 of 42 (64.3%) of the test ewes bred before September 16 and 12 of 35 (34.3%) from September 16 to October 25 (table 4).

Dutt (1951) observed fertilzation failure in 44.9% of all eggs ovulated early in the breeding season.

Defective Ova. Part of the fertilization failure appeared to be due to morphologically abnormal ova. By microscopic observation all ova recovered from 16.7% (7 out of 42) of the ewes bred early in the breeding season (before September 16, table 4) and 2.9% (1 out of 35) later in the season (through October 25) were classified as mor-

phologically abnormal. The difference between these percentages approached significance (P between .06 and .05). Dutt (1951) found a relatively large proportion of abnormal ova (20.5%) early in the breeding season.

TABLE 4. CHANGE IN BREEDING PERFORMANCE OF EWES WITH ADVANCE OF THE SEASON

Ewe performance	Interval			
	Aug. 1–Sept. 15		Sept. 16–Oct. 25	
Fertilization failure		64.3[a]		34.3[b]
(1) defective ova	16.7		2.9	
(2) poor sperm	47.6		31.4	
Ewes returning to heat due to embryonic death up to 18 days		10.2[c]		6.5[d]
Services resulting in pregnancies (18-day non-returning		25.5		59.2
Total		100.0		100.0

[a] $(100-\frac{15}{42}=100\%$ minus percentage of total ewes with some ova fertilized before September 16.

[b] $(100-\frac{23}{35}=100\%$ minus percentage of ewes with some ova fertilized after September 15.

[c] $100-(64.3+25.5)$.

[d] $100-(34.3+59.2)$.

Embryonic Death

The quantity (100 minus the ratio of the percentage of 18-day non-return ewes to the percentage of ewes with some fertilized ova) before September 16 was 28.6% (100–25.5/35.7) as compared with 9.9% (100–59.2/65.7) for the remaining period. This is the estimated percentage of ewes in which fertilization occurred and was followed by prenatal mortality of all embryos present. This could account for failure to produce lambs in about 10.2% (table 4) of all ewes bred before September 16 and 6.5% bred after that date, the difference between which was not significant statistically as determined by a Chi square test for interaction as used by Rao (1952), (P between .70 and .80).

The embryonic death for the entire season as estimated from 18-day non-returns from all services was 20.4% (100–39.3/49.4); whereas the embryonic death between the 18th day and lambing for the entire season was estimated at 9.3% (4.6/49.4). This would seem to indicate

that the flock incidence of embryonic death was greater during the first 18 days after service than during the remainder of gestation.

Lowered Fertility in Rams

Ram fertility (Hampshire and Shropshire), as judged by the percentage of test ewes (having morphologically normal ova) in which some ova were fertilized, was much lower before September 16, 42.8% (15 out of 35) than afterwards, 67.6% (23 out of 34). The difference between these was significant statistically. Thus, poor semen (table 4) could account for fertilization failure in 47.6% of all ewes bred before September 16 and in 31.4% of the ewes bred subsequent to this time. This lower fertility of the rams early in the season is presumed to be due in part to the higher environmental temperatures which occurred during the early part of the breeding season. Moore and Oslund (1924), Phillips and McKenzie (1934), McKenzie and Berliner (1937), McKenzie and Colvard (1938), Gunn *et al.* (1942) and others have demonstrated the deleterious effect of heat on spermatogenesis and fertility. Dutt (1951) observed that 24.4% of the eggs ovulated early in the breeding season failed to develop into lambs due to fertilization failure in morphologically normal ova. Dutt and Simpson (1954) have shown that cool temperatures (45° to 48° F.) during the summer months improved ram fertility markedly over that of controls kept at the normal environmental temperatures.

The lowered fertilizing capacity of rams could account for the largest proportion of the high return rate of ewes in the early part of the breeding season.

Semen Quality and Fertility. There tended to be a higher fertilization rate when semen quality was high as evaluated by sperm concentration, motility and methylene blue reduction time. However, statistical analysis did not show these correlations to be significant.

The within-ram correlation between percentage motility and fertility approached significance ($r=.297$, P approx. .08). However, the between-ram correlation between motility and fertility was negative ($r=-.93$) but (on the small number of rams) insignificant.

Semen quality, as evaluated in this experiment and with the range of variation exhibited, was not a good index of fertility. However, the number of rams used was small.

Anderson (1941) Lasely and Bogart (1943), Swanson and Herman (1944), Mercier and Salisbury (1947) and others have found significant but small correlations between fertility and certain semen characteristics

in cattle. The only semen characteristics with coefficients greater than 0.1 or less than −0.1 found by Wiggins *et al.* (1953), which were significantly correlated with the percentage of ewes lambing, were percent normal sperm ($r=.435$), percent abnormal heads ($r=-.350$) and percent live, normal sperm ($r=.292$).

Though several investigators have at times found rather high correlations between certain semen characteristics and fertility, subsequent investigation has generally brought disagreement.

Summary

Breeding records of the University of Wisconsin Hampshire and Shropshire flocks for the years 1947 through 1952 were analyzed.

The average fertility from first service for the years in which breeding was begun August 1 was significantly lower than when breeding was delayed until September 1.

The fertility results from first service in both the Hampshire and Shropshire ewes were analyzed by dividing them into two-week intervals according to breeding dates. In general, fertility increased with the advance of the season up to October 1, a highly significant change.

Estimates of fertilization rate and embryonic death were made in 1952. Embryonic death was estimated by comparing 18-day non-return rates in the University of Wisconsin Hampshire and Shropshire flocks with the fertilization rates (on a ewe basis) in western ewes bred to the same purebred stud rams.

Ram fertility was significantly lower before September 16 than afterwards.

Of the 77 western test ewes from which ova were recovered, 64.3% failed to have any fertilized ova before September 16 compared with 34.3% for the remaining period. All ova recovered from 16.7% of the ewes bred before September 16 and 2.9% bred thereafter were classified as morphologically abnormal ($P<.06$), accounting for part of the fertilization failure. The remainder in each case may be attributed to poor sperm.

The estimated embryonic death (100 minus the ratio of the percentage of 18-day non-returns to the percentage of ewes with some fertilized ova) before September 16 was 28.6% as compared with 9.9% for the remaining period. The differences between the 18-day non-return rates and the fertilization rates for the ewes bred before September 16 and for those bred later were not significant.

Embryonic death appeared to be greater during the first 18 days

following service (20.4%) than during the remainder of gestation (9.4%).

No significant correlations were found between semen quality, as evaluated by various tests, and fertility.

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THE EFFECTS OF SHEARING AND LEVEL OF FEEDING ON FERTILITY OF RAMS [1]

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LOW fertility in sheep early in the breeding season has presented a major problem to producers of spring lambs who are trying to take advantage of favorable market or pasture conditions existing during the spring and early summer. Earlier studies (Dutt, 1951; Hulet *et al.*, 1956) have suggested that the major cause of early-season infertility is lowered fertility of the rams.

McKenzie and Berliner (1937) and Phillips and McKenzie (1934) have suggested that a heavy fleece and a fat condition of rams might be detrimental to their fertility. Inasmuch as the early part of the breeding season in many areas is associated with the frequent occurrence of hot days and because high temperatures appear to be detrimental to both semen quality and fertility (Fukui, 1923, McKenzie and Berliner, 1937, Gunn *et al.*, 1942, Dutt and Bush, 1955, Hulet *et al.*, 1956, and others), it was postulated that sheared rams might be able to maintain lower body and/or testicular temperatures during hot weather than unsheared rams and therefore be more fertile. It was similarly postulated that thin rams might be able to maintain lower body temperatures than fattened rams and therefore be more fertile.

Materials and Methods

In mid-January, 1953, 25 short-yearling, native rams of mixed breeding (Hampshire, Shropshire, Oxford and Corriedale) were divided at random into two lots. The following year in early February another group of 32 rams of similar type and age to those used in 1953 were likewise randomized into two lots. One lot each year was given an average of a little over 2 lb. of grain daily (2.29 lb. in 1953 and 2.04 lb. in 1954) throughout the experiment plus what hay they would eat. (See footnote, table 1 for composition of grain mixture and description of hay.) The other group received only hay. All rams were sheared in April. One-half of each of the feed lots (selected at random) was resheared

[1] Paper from the Department of Genetics (No. 603) and the Department of Animal Husbandry. Published with the approval of the Director of the Agricultural Experiment Station. Supported in part by the Research Committee of the Graduate School from funds supplied by the Wisconsin Alumni Research Foundation.

at monthly intervals throughout the remainder of the experiment. The other half was not sheared again until all breeding was completed in the fall.

A group of 85 short-yearling, native ewes in 1953 and another group of 87 ewes of similar description (similar breeding to rams) in 1954 were each divided at random into two lots. One lot received the rough-age-plus-grain ration described above except that the grain mixture in the ration averaged only about 2 lb. per head daily. The other lot was limited to roughage. The ewes were on sweet clover pasture and the rams on young wheat or mixed grass pasture as a substitute for hay for approximately one month during the summer. All environmental conditions other than treatment were held as nearly equal as possible between lots.

Five randomly selected rams finally represented each treatment (at breeding) each year with the exceptions that rams which would not serve the artificial vagina or had some abnormality not due to treatment were excluded.

Breeding (hand mating) was performed from August 20 to October 20, when the sheep were yearlings. Each ram was mated to two ewes from each of the two different feed level groups. One of these two ewes was slaughtered at three days post-coitum and the ova recovered to determine fertilization; the remaining ewe was slaughtered at 40 days post-coitum (if she did not return to heat earlier) to determine embryo survival. No fertility data were kept from ewes with observable reproductive abnormalities. The extra, unbred ewes were used to replace ewes which did not for some reason yield the necessary information.

Data on various carcass characteristics were obtained subsequent to slaughter.

In 1953 semen studies were begun on July 20 and continued throughout the remainder of the experiment. Semen collections were made from each ram (where possible) by means of the artificial vagina just prior to each mating. When no breeding occurred collections were made at least once every week.

The following semen observations were made: (1) Mass movement of sperm (swirl) graded from 0 to 4; (2) Motility (estimated percent of sperm showing forward motion); (3) Methylene blue reduction-time (MBRT); (4) Concentration and (5) Volume.

Mass movement was observed immediately following collection. Motility and MBRT were observed within two hours following collection.

In 1954 semen samples were obtained from each ram during the first

and third weeks of September and the following observations were made: (1) Mass movement (swirl) graded from 0 to 4 immediately after collection; (2) Motility at 2 hours and 10 minutes after collection and motility at 5 hours and 40 minutes after collection (diluted at 2 hours and 10 minutes with 0.1 molar sodium citrate solution and maintained in a water bath at approximately 29° C.); (3) Concentration and (4) Volume.

At the time of slaughter it was found that the scrotum of one of the sheared, roughage-fed rams (1954) was completely adhered to the testes and a large abscess was found on the tail of the right epididymis. It was thought that this condition was not a result of the experimental treatments; therefore, the fertility data obtained from this ram were not included in the analysis.

The error terms for the various analyses of variance and covariance have been selected by determining the variance components for each mean square according to a "rule of thumb" method devised by Henderson (1954).

Results and Discussion

The Effect of Level of Feeding on Carcass Characteristics and Wool

All groups receiving the grain mixture (in both 1953 and 1954) gained much more rapidly than the roughage-fed groups. However, those on roughage only remained thrifty. At the conclusion of the experiment there were marked differences in carcass size and finish grade with practically no overlap between groups.

The rams receiving grain averaged about 39 lb. heavier in carcass weight and graded an average of low prime in 1953 and high choice in 1954. The rams receiving only roughage graded an average of low choice in 1953 and average utility in 1954. The grain-fed rams had heavier fleeces on the average than those receiving only roughage. However, there was no significant difference in either year when adjustment was made for carcass weight.

Semen Quality

The group means (table 1) for each semen characteristic studied in 1953 indicate the highest semen quality for the sheared, roughage-fed rams in all cases. The sheared, roughage-plus-grain-fed rams were second in each semen quality characteristic; the unsheared, roughage-fed rams third; the unsheared, roughage-plus-grain-fed rams lowest in each in-

stance. However, only the difference in mass movement score between the sheared and unsheared rams was found to be significant statistically when tested against the among-ram within-treatment mean square ($P<.05$). The change (improvement) in semen quality with the advance of the season was significant only for the methylene blue reduction test.

TABLE 1. THE EFFECT OF SHEARING AND LEVEL OF FEEDING ON SEMEN QUALITY AND FERTILITY OF NATIVE, YEARLING RAMS (1953 AND 1954)

		Semen quality [a]				Fertility		
Ram treatment	Year	No. of sperm/ c. mm. (1000)	Mass move score	% Forward motion (motility)	MBR time (sec.)	Ewes [b] with fert. ova at 3 days	Ewes [b] with embryos at 40 days	% Fert. of rams [c]
Sheared	1953	2476	2.55	56.8	113.2	9/10 [b]	5/10	70
	1954	1980	3.60	53.7		9/10	7/10	80
R + G								
Unsheard	1953	2054	1.75	47.8	175.0	5/10	1/10	30
	1954	2319	3.80	58.7		8/10	4/10	60
Sheared	1953	2716	3.10	63.8	93.3	8/10	8/10	80
	1954	2132	3.90	63.0		8/8	5/8	81
R only								
Unsheared	1953	2082	2.15	54.2	167.5	6/10	5/10	55
	1954	2573	3.90	55.4		7/10	4/10	55
Average		2292	3.09	56.7	132.5	77.5%	50.2%	63.9

[a] Figures are the group means.

[b] Numerator is number ewes with fertilized ova or with embryos; demoninator is number ewes studied.

[c] Percentages are based on the unweighted means from all 3-day and 40-day fertility information.

R=roughage, what the rams would clean up. Mostly alfalfa, grass mixed hay (av. qual.).

G=grain mixture of 5 lb. ground corn, 3 lb. whole oats, 1 lb. bran, and 1 lb. linseed meal Average, 2.29 and 2.03 lb. per head per day for 1953 and 1954, respectively.

The group means (table 1) for each semen characteristic indicate less consistent differences in 1954 than in 1953. The rank of treatment groups for semen quality in 1954 was also somewhat at variance with the rank of treatment groups in 1953. In 1954 only the sheared, roughage-fed group, which had the highest semen quality in each characteristic except sperm concentration, was quite similar to the comparable treatment group in 1953. This group was also highest in fertility in both years. None of the between-treatment group differences for the various measures of semen quality was significant when tested against the among-ram within-treatment mean squares. There was, however, a significant decrease in sperm concentration and motility between the first and third week (the two times studied) when tested against the time×ram-within-treatment mean squares.

Fertility

The mating of the sheared rams to both roughage-plus-grain and roughage-fed ewes resulted in a larger proportion of ewes having fertile ova at three days (17 out of 20 in 1953 and 17 out of 18 in 1954, table 1) than resulted from the mating of unsheared rams to ewes from the same treatment groups (11 out of 20 in 1953 and 15 out of 20 in 1954). When the chi square values for the two years were pooled, this difference was significant ($P<.02$). Likewise, when ewes from these same two treatments were bred to the sheared and unsheared rams and examined

TABLE 2. LOCAL CLIMATOLOGICAL DATA OBTAINED FROM THE WEATHER STATION IN NORTH HALL, MADISON, WISCONSIN

Month and year	Temperature ° F			Days 91° F or more	Days 86–90° F.	Days 81–85° F.	Relative humidity range [a]
	Av.	Highest	Lowest				
							%
July, 1953	72.4	91	55	2	3	12	28–99
July, 1954	72.5	89	55	0	9	7	31–98
Aug., 1953	72.9	96	57	7	3	6	25–98
Aug., 1954	69.2	87	54	0	2	5	30–98
Sept., 1953	62.4	99	33	3	2	3	18–97
Sept., 1954	63.6	92	43	1	4	0	28–99

[a] Data secured from Truax Field, Madison.

for normal embryos at 40 days it was again found that the ewes bred to the sheared rams had larger proportions of normal embryos (13 out of 20 compared with 6 out of 20 in 1953 and 12 out of 18 compared with 8 out of 20 in 1954, table 1). Again when the chi square values for the two years were pooled the difference was significant ($P<.02$). When the above fertility data were pooled (3 day plus 40 day) over the two years, the difference in the proportions of fertile ewes from matings to the two groups of rams was highly significant ($P<.01$), favoring the sheared rams.

When the effects of shearing on fertility for the two years (1953 and 1954) are compared it may be seen that the effect of shearing was more marked in 1953 than in 1954. When the 3- and 40-day fertility data for 1953 were pooled the difference in the proportions of fertile ewes from matings to the two groups of rams was highly significant. However, when the data were treated similarly for 1954 the chi square probability only approached significance (P between .10 and .05).

It is suggested that differences in ambient temperatures between the two years is the most probable reason for this year difference. A comparison of the prevailing ambient temperatures for the months of July, August and September for the two years (table 2) indicates that the

breeding season in 1953 was characterized by hotter weather than in 1954. The highest temperature for July, 1954, was slightly lower and there were fewer days of 91° F. or above in July of 1954 than in July of 1953. Similarly comparing the months of August for the two years, the average temperature and the highest temperature in August, 1954, were lower and the days of 91° F. or more were considerably fewer than in 1953. The average temperatures for September in the two years were similar, but there were more days above 91° F. in 1953 than in 1954.

TABLE 3. AVERAGE BODY TEMPERATURES OF RAMS AT REST

Year	Total no. observations	Body temperature ° F.			
		Roughage + grain		Roughage only	
		Unsheared	Sheared	Unsheared	Sheared
1953	144	104.2	103.3	103.7	102.8
1954	300	103.4	103.0	103.0	102.6

Thus it appears possible that a heavy fleece of wool might have put the unsheared rams to a greater disadvantage relative to the other treatment group in 1953, when weather conditions were hotter, than in 1954.

No significant difference in fertilizing ability was found between the rams on the two different levels of feeding. However, these rams appeared to lack the ability to fatten easily, and the grain-fed rams did not become nearly so fat as expected. This was especially true the second year as was shown by the carcass grades and dressing percentages.

A temperature study made on these same rams during the course of this experiment (table 3) showed that the sheared rams had significantly lower rectal temperatures than the unsheared groups in both years but that the rams which received only a roughage ration had significantly lower body temperatures only in 1954. This is in agreement with work done by Fletcher and Reid (1953) and Lee (1950).

Robinson and Lee (1947), Reik *et al.* (1950), Knapp and Robinson (1954) and others also observed that a high plane of nutrition had an important effect on body temperature under hot conditions.

Discussion

These results in conjunction with the studies of other investigators indicate that any factor which tends to increase body temperature, such as a heavy fleece of wool, exercise, and large deposits of fat at high

ambient temperatures as well as high ambient temperature itself and fever tends to decrease fertility. Any factor, therefore, which tends to prevent body temperature from rising above a certain critical level might justifiably be studied for its ability to maintain fertility early in the season. Dutt and Simpson (1954) and Dutt and Bush (1955) at the Kentucky station subjected rams to controlled temperatures and found that those maintained at 45° to 48° F. during the summer months had significantly higher fertilization rates than control groups.

The fact that the fertility of the sheared rams was significantly higher than that of the unsheared rams without there being a significant difference in semen quality indicates that marked changes in semen quality do not necessarily accompany the changes in fertility brought about by differences in temperature.

Summary

Groups of approximately 20 rams and 80 ewes in 1953 and similar groups in 1954 were each divided as lambs into two lots, one of which received roughage plus grain (a fattening ration) and the other only roughage. All were sheared in April and half of each group of rams was resheared at monthly intervals until breeding was completed. Breeding was from August 20 to October 20, when the sheep were yearlings. Each ram was mated to two ewes from each lot. One of these two ewes was slaughtered at three days and the ova recovered to determine fertilization; the remaining ewe was slaughtered at 40 days to determine embryo survival. In addition, various semen characteristics were studied during the breeding period.

The sheared rams had a significantly higher fertilization rate than the unsheared rams. Likewise, a significantly larger proportion of ewes bred to the sheared rams had normal embryos at 40 days of gestation than did those bred to the unsheared rams. No difference in fertilizing ability was found between the rams on the two feeding levels.

The sheared rams had significantly lower rectal temperatures than the unsheared groups in both years but the rams which received only a roughage ration had significantly lower body temperatures only in 1954.

No significant relationship was found between various measures of semen quality and fertility in either year though the group with the highest fertility in each year (sheared, roughage-only group) also had the best semen quality each year.

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THE RELATIONSHIP OF THYROID ACTIVITY TO LACTATION, GROWTH, AND SEX IN SHEEP [1]

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THE thyroid gland has been shown to be associated with many physiological processes important to animal production. Artificially induced hypo- or hyper-thyroidism has affected the growth rate of livestock (Simpson, 1924; Todd and Wharton, 1938; Reineke and Turner, 1941; Brody and Frankenbach, 1942; and Koger and Turner, 1943). Graham (1934), Reineke (1943), Archibald (1945) and others have reported the effect of hypo- or hyper-thyroidism on milk production. A high correlation between milk yield and lamb gains has been reported by Bonsma (1944) and Guyer and Dyer (1954). Moreover, a varying level of thyroid activity has been found to be associated with the different sexes of some species (Schultze and Turner, 1945; Monroe and Turner, 1946).

The variation between individual animals in growth rate and milk production is of great importance to the livestock industry. This research was designed to study the relationship of thyroid secretion to growth rate and milk production in sheep. Further work was also performed to determine thyroid secretion rates of the different sexes.

Experimental Procedure

Eleven Shropshire ewes were used to determine the relationship between the thyroid output turnover half-time of I^{131} and milk production as measured by the growth rate of nursing lambs up to 3 weeks of age. Seven ewes were nursing twin lambs while the other four had single lambs. They were treated as separate groups for analysis of the data.

Birth weights and 3-week weights were taken on the lambs. The thyroid determinations were made in March during the latter part of this 3-week period. All ewes were fed a similar ration and no creep was available for the lambs. Iodized salt was fed free-choice.

In studying the relationship of thyroid secretion to growth rate

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and sex, 12 ewe lambs, 5 ram lambs, and 4 wether lambs of the Shropshire breed were used. They were fed as one group in a dry lot for 3 weeks after weaning and prior to the experimental period. After an initial weight was taken, the lambs remained on feed for one month and then a final weight was taken. During this one month feeding period (August–September) the daily thyroid secretion rate was determined. Ages of the lambs ranged from 153 to 175 days at the start of the trial.

In both of these experiments, the sheep were injected subcutaneously with 1 uc. of I^{131} per pound of body weight. The neck and one foreleg were sheared before the first counts were taken. In the lactating ewes, 10 external thyroid counts were taken over a 12-day period following injection of I^{131}. Counts were taken with an end-window Geiger-Muller tube. All counts were read on a count rate meter (Nuclear, Model 1615–A) set at 2% statistical error. The thyroid counts were corrected for instrument variation, for body background by the foreleg count and for physical decay. The output turnover halftime computed for each ewe was correlated with the 3-weeks gain of her lambs.

In determining the daily thyroid secretion rate of the lambs in the second experiment, a refinement of the technique previously reported by Henneman (1955) was used. A scintillation counter (Nuclear Model DS–1) was substituted for the Geiger-Muller tube. This increased materially the efficiency of counting gamma rays. Also, external counts were taken every other day as compared to every third day. Varying levels of L-thyroxine [4] were injected subcutaneously daily and at least two external counts were taken for each level of thyroxine injection. This technique made it possible to obtain a greater number of counts which should have increased the accuracy of the estimate of the individual lamb's daily thyroid secretion rate.

Results and Discussion

The Relationship of Thyroid Output to Lactation

The data on thyroid output for the eleven ewes and the 3-weeks gain of their lambs are presented in table 1. Statistical analysis was limited to the ewes with twin lambs. The coefficient of correlation between the thyroid output half-time of the seven lactating ewes with twin lambs and the 3-weeks gain of the suckling twin lambs was —0.68 and the regression line was $\hat{Y}=22.84-0.026x$. with only seven ewes this corre-

[4] Supplied by Glaxo Co., Greenford. Middlesex, England, and further purified by alcohol extraction and successive recrystallization.

lation is not statistically significant. These data suggest that the ewes suckling twin lambs which have a higher thyroid activity tend to secrete more milk as measured by gains of their lambs up to three weeks of age.

Inspection of the data in table 1 shows no apparent relationship between thyroid activity of four lactating ewes and growth of their

TABLE 1. THE THYROID OUTPUT RATE ($t_{1/2}$) OF LACTATING SHROPSHIRE EWES AND THREE WEEKS GAIN IN WEIGHT OF THEIR LAMBS

Ewe No.	Ewe weight	Thyroid output ($t_{1/2}$)	Lamb No.	Individual 3-weeks gain	Total 3-weeks gain of twins
	lb.	hr.		lb.	lb.
			682	10.50	
546–48	145	144.7	683	10.00	20.50
			734	12.00	
911–50	150	152.0	735	9.00	21.00
			741	11.50	
552–48	152	161.8	742	8.00	19.50
			739	6.50	
924–50	143	184.7	740	7.50	14.00
			676	8.75	
657–49	149	212.0	677	8.00	16.75
			743	7.25	
645–49	144	235.2	744	8.50	15.75
			678	7.50	
644–49	137	358.3	679	7.25	14.75
H30–47	167	178.1	685	13.75	
215–47	138	271.3	738	13.75	
232–47	146	281.3	674	13.50	
212–47	135	338.2	746	9.50	

single lambs. However, this may be an indication that even ewes with low thyroid activity produce enough milk for the rearing of a single lamb. Barnicoat *et al.* (1949) and Guyer and Dyer (1954) observed that ewes suckling twins produced a larger amount of milk than ewes suckling singles.

Schultze and Turner (1945) reported that lactating goats producing an average of 2.6 lb. of milk per day had a daily d,l-thyroxine secretion rate of 1425 mcg., whereas the same goats in advanced lactation, producing an average of 1.8 lb. of milk per day, secreted 1000 mcg. of d,l-thyroxine daily.

The Relationship of Thyroid Secretion Rate and Sex

An estimate of daily l-thyroxine secretion was made in individual, intact sheep using the technique described earlier. Estimates of secretion rates for rams, wethers, and ewes are presented in table 2. The differences in secretion rate due to sex were studied by analysis of variance. The average daily l-thyroxine secretion rate per cwt. in different sexes of lambs were: ewes, 0.08 mg.; rams, 0.07 mg.; and wethers, 0.05 mg. The secretion rate for ewe lambs was significantly more than for wether lambs ($P<.05$). Ram lambs were not significantly different in secretion rate from either ewe or wether lambs.

TABLE 2. THE DAILY THYROID SECRETION RATE AND THIRTY DAY GAINS OF RAM, WETHER, AND EWE LAMBS

Ewe No.	L-Thyroxine secretion	30-day gain	Ram No.	L-Thyroxine secretion	30-day gain	Wether No.	L-Thyroxine secretion	30-day gain
	mg.	lb.		mg.	lb.		mg.	lb.
678	0.06	4.0	686	0.08	7.0	680	0.03	11.0
682	0.09	9.0	688	0.08	16.0	733	0.04	7.0
684	0.13	11.0	731	0.07	4.0	737	0.07	7.5
718	0.04	2.5	732	0.05	9.0	741	0.05	4.0
719	0.08	7.0	739	0.05	9.0			
720	0.09	11.0						
735	0.06	4.0						
738	0.08	6.0						
740	0.10	13.5						
743	0.06	6.5						
744	0.08	5.5						
746	0.11	8.5						
Means	0.08	7.4		0.07	9.0		0.05	7.4

Riddle (1929) reported a larger thyroid gland in the female pigeon than the male. Marza and Blinov (1936) observed a higher secretory activity of the thyroid in the female pigeon than the male as indicated by histological examination. Schultze and Turner (1945) reported a higher thyroid secretion rate in the hen than in the rooster. They also observed a 16% decrease in castrated male fowl as compared to normal males. Sherwood *et al.* (1933) observed a decreased metabolic rate in castrated rats.

While numbers are limited, the gains of ram and wether lambs compare favorably to the gains of ewe lambs even though their thyroid activity tended to be at a lower level than ewes. This would indicate that other factors besides thyroid secretion rate are involved in differences in weight gains between the sexes when feeding and manage-

ment are similar. Data on feed consumption and efficiency were not obtained in this study.

The Relationship Between Thyroid Secretion Rate of Ewe Lambs and Growth Rate

Sufficient numbers of ewe lambs were available to arrive at an estimate of the relationship between thyroid secretion and gain in weight (table 2).

A correlation coefficient of 0.81 was obtained between daily l-thyroxine secretion rate and the growth of ewe lambs. This is statistically significant at the 1% level and indicates that ewe lambs with a higher thyroid activity gained faster than those with a lower thyroid activity as expressed by the regression line, $\hat{Y}=-1.51+108.46x$.

Glazener and Shaffner (1948) reported that rapid growing strains of Barred Plymouth Rock and New Hampshire Red chickens had a higher thyroid activity than slow growing strains. Kunkel *et al.* (1953) reported an optimum level of protein-bound iodine associated with rapid gains in beef cattle. Over the range of thyroid secretion rates found in the present study there is a straight line proportionality between thyroid secretion and gain in weight.

Summary

Shropshire ewes with a high thyroid activity as measured by thyroid output half-time tended to produce faster gaining twin lambs to three weeks of age than ewes with low thyroid activity. It is believed that the faster gains of these young lambs is due largely to increased milk consumption.

Daily l-thyroxine secretion rates per hundred pounds live weight were determined by the extrapolation technique in individual intact Shropshire lambs. The secretion rates by sex were: ewes, 0.08 mg.; rams, 0.07 mg.; and wethers, 0.05 mg. The ewe lambs were secreting significantly more l-thyroxine than wether lambs ($P<.05$). The thyroxine secretion of ram lambs was not significantly different from ewe or wether lambs.

Ewe lambs with a higher thyroid secretion rate tended to gain more rapidly during a 30-day feeding period. A correlation coefficient of 0.81 was obtained between daily l-thyroxine secretion rate and 30-day gain which is significant at the 1% level. This relationship is expressed by the regression equation, $\hat{Y}=-1.51+108.46x$; where Y=lb. gained and x=mg. thyroxine secreted daily.

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SOME ABNORMALITIES OF THE BOVINE ENDOMETRIUM [1]

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HALLMAN (1919) described abnormalities of reproductive organs of four cows slaughtered because of sterility and concluded that the deeply seated lesions of the uterine mucosa represented foci of infection with microorganisms of low virulence which were responsible for the reproductive disturbances of these animals. In recent years several investigators, including Miller (1950), Simon (1951), Brus (1954) and Kampelmacher (1954), have employed the biopsy technique for the purpose of a microbiological and histological analysis of the endometrium in cases of bovine sterility. These investigators, who were primarily concerned in detecting cases of endometritis, observed structural abnormalities similar to those described by Hallman (1919).

In the course of our studies of the bovine uterus we have also encountered similar structural abnormalities. In this paper a more detailed characterization of these abnormalities is recorded and the relationship of these abnormalities to the breeding performance of the cattle involved has been determined.

Materials and Methods

The tissues used in the present work were obtained from two populations of cattle. Fifty-five cows and heifers were from the U.S.D.A. dairy herd at Beltsville and included normally cycling cattle killed at various stages of the estrous cycle or during pregnancy. Tissues from 22 additional animals were obtained from L. E. Casida of the University of Wisconsin. These cattle came from a number of Wisconsin herds and included both apparently normal and repeat-breeder cows and heifers.

The subjects from the Beltsville herd consisted of 25 animals with good breeding records and 30 animals with poor breeding records. Tissue specimens from each of these animals were obtained immediately after slaughter and included sections from the corpus uteri near the area of bifurcation and from each uterine horn near the utero-tubal junction. Tissues were fixed in cold acetone and Carnoy's and Bouin's fluid, and

[1] The work reported in this paper has been conducted as a part of the Northeastern Co-operative regional project NE-1, "Causes and prevention of reproductive failures in cattle".
[2] Dairy Husbandry Research Branch, A.R.S., Beltsville, Maryland.

some were fixed in absolute alcohol and Zenker's fluid. Between 6 and 15 different blocks of tissues were processed for each animal.

The subjects from the Wisconsin herds consisted of 12 "first service" animals (virgin heifers or cows which had been bred only once during the current reproductive cycle) and 10 repeat-breeder cows. These animals were slaughtered from 11 to 16 days after breeding. Tissue specimens from these animals were usually obtained from the upper third of each of the uterine horns and fixed in cold acetone and Carnoy's fluid, respectively, giving a total of four blocks of tissues for each animal. The tissues from the Wisconsin cattle were fixed and embedded at the University of Wisconsin [3] and sent to Beltsville for sectioning, staining, and histochemical processing.

The processing and histochemical determination of alkaline glycerophosphatase activity, glycogen, and periodic acid-Schiff (PAS) positive substances were the same for both groups of cattle as given earlier (Moss *et al.*, 1954a, 1954b).

Results

The abnormalities which have been encountered involve the presence of distinctive nodules in the endometrium or distinct changes of the uterine glands and periglandular connective tissue.

Nodules

These consist of masses of small round cells with dense nuclei (lymphocytes) aggregated to form spherical or oval structures which are distributed at random within the otherwise normal endometrial stroma (fig. 1). In most instances nodules are clearly separated from the endometrial stroma and very often have a fibrous connective tissue capsule around them. Many nodules were invaded by small blood vessels. The cells of the nodules are usually phosphatase inactive, but occasionally some cells show moderate activity. Nodules do not contain glycogen or PAS positive material.

Abnormalities in Uterine Glands

Normally, glands in the intermediate and basal areas of the endometrium are embedded in connective tissue trabeculae which traverse the loose (areolar) endometrial stroma. These trabeculae consist primarily of connective tissue fibers and fibroblasts, but some other small

[3] We are indebted to Harold W. Hawk of the Department of Genetics, University of Wisconsin for the help given us in the collection and preparation of the tissues.

Figure 1. Nodules in the endometrial stroma near the area of bifurcation. Stained with hematoxylin and eosin. ×98. 2. Encapsulated gland in the anterior portion of the endometrial stroma. Stained with hematoxylin and eosin. ×98. 3. Adjacent section to that of figure 2, stained for alkaline glycero-phosphatase activity. Note absence of activity in the inner portion of the periglandular connective tissue. ×98. 4. Encapsulated gland in the anterior portion of the endometrial stroma stained with the PAS technique. Note high PAS positive material in the epithelium of this gland and its absence from other (normal) glands. ×98. 5. Cystic (upper) and encapsulated (lower) gland in the endometrial stroma near the area of bifurcation. Stained for alkaline glycero-phosphatase. Note presence of activity in the periglandular connective tissue of the upper gland and its absence from the lower one. ×98. 6. Large branched cystic gland in the endometrial stroma near the area of bifurcation. Stained with the PAS technique. ×110.

round stroma cells, including plasma cells, mast cells, glycogen containing cells, and leucocytes may also be seen dispersed at random in the trabeculae. In the superficial layer of the endometrium the gland lumina are wider, gland cells are taller and the periglandular connective tissue consist predominantly of the same small round stroma cells which form the densely cellular layer of the subepithelium. One striking characteristic of the periglandular connective tissue of all normal uterine glands, irrespective of the location in the endometrium and changes during the cycle and pregnancy, is the high alkaline phosphatase activity, the activity always being highest at the base of the glands (Moss *et al.*, 1954b). Glycogen granules may be present, especially in the superficial layer, but PAS positive material is absent from the periglandular connective tissue except in the thin basement membrane of some glands.

In addition to normal glands, two types of glandular abnormalities were found in the uteri of some animals. One type involves primarily a modification of the periglandular connective tissue, the other a modification of the gland cells proper.

A typical abnormal gland of the first type is seen in figure 2. The gland cells themselves do not differ appreciably from those of normal glands. The lumen of the gland, however, is increased in size and the periglandular connective tissue is hypertrophied and distinctly modified. Even in hematoxylin and eosin stained slides a more or less pale, thick capsule, consisting of spindle-shaped cells which are closely packed and parallel to each other and which have slender nuclei, distinctly differentiates these glands from other neighboring normal glands. A characteristic feature of such glands is the absence of alkaline phosphatase from this periglandular capsule (fig. 3). The distal border of the gland cells and the luminal secretion usually have high amounts of alkaline phosphatase, but the rest of the cell cytoplasm is inactive.

The disappearance of alkaline glycero-phosphatase from the periglandular connective tissue is always associated with the appearance of the spindle-shaped cells. The width of the phosphatase inactive halo around these glands always corresponds closely to the extent of spread of these spindle-shaped cells. These glands are also easily identified on PAS stained slides by the staining of the periglandular capsule. The gland cells also may stain heavily with the PAS technique (fig. 4).

Another glandular abnormality is illustrated in figures 5 and 6 which show typically cystic glands which have wide branched lumina and low cuboidal or flattened epithelium. The periglandular connective tissue of these glands, ordinarily, is not altered and its phosphatase activity is also

similar to that seen around normal glands. However, occasionally some glands are encountered which are typically cystic and which also have thick bundles of PAS positive periglandular fibrous tissue. Apparently such glands represent a combination of disturbances in both the gland cells as well as in the periglandular connective tissue.

Distribution of Abnormalities

The endometria of all the animals were examined to determine the distribution and type of abnormalities present. When present, these were seen on most sections and blocks of tissue. All types of abnormalities were more frequent and more pronounced in the corpus uteri than in the uterine horn. Occasionally abnormalities were seen in the sections from only one or two tissue blocks. The occurrence of endometrial abnormalities among all the animals is given in table 1.

In a total of 55 animals of the Beltsville group at least one type of abnormality was present in 25 animals. Dividing this population of 55 animals into 2 categories, one with no obvious signs of breeding difficulty and the other with poor breeding qualities, it will be observed that out of 25 animals of the first category, abnormalities were present in 4 animals (16%), whereas, out of 30 animals of the second category, abnormalities were present in 21 animals (70%).

The types of abnormalities found varied between individuals. Nodules were not found in any of the 25 animals with good breeding qualities but appeared in eight out of 30 (27%) animals which had breeding difficulties. Four out of these eight also had encapsulated and one had both encapsulated and cystic glands in addition to nodules. Cystic glands were encountered in only five animals, two of which were good and three poor breeders. Encapsulated glands were also present in three of these five animals. Encapsulation of glands was the most frequent abnormality. The occurrence of nodules alone and of cystic glands alone is statistically not significantly related to breeding performance, but a very high significance is found for the simultaneous occurrence of encapsulated glands and breeding difficulty. Thus, encapsulation of glands, irrespective of whether or not other abnormalities were also present, was found in 17 out of 30 (56%) poor breeders and only in three out of 25 (12%) good breeders.

The data thus far presented, which include only the animals from the Beltsville herd, suggest an association between the presence of endometrial abnormalities (encapsulated glands) and breeding difficulties. However, no such relationship was found among the animals from the

TABLE 1. INCIDENCE AND TYPES OF ENDOMETRIAL ABNORMALITIES FOUND IN COWS WITH GOOD AND POOR BREEDING RECORDS

Group	Breeding record	Number of animals	Occurrence of endometrial abnormalities						
			None	Nodules	Cystic glands	Encapsulated glands	Nodules + Encaps. glands	Cystic + Encaps. glands	Nodules + Cystic + Encaps. glands
Beltsville	good	heifers 7	5		1	1			
		cows 18	16			1		1	
	poor	heifers 15	3	1		6	4	1	
		cows 15	6	2	1	5			1
Wisconsin	good	heifers 7	7						
		cows 5	3	2					
	poor	heifers 0							
		cows 10	8	1		1			

Wisconsin herds. Among these only two individuals in each of the good and poor breeder categories showed endometrial abnormalities.

This difference between the two populations of cattle may possibly be a result of some differences in tissue sampling and population. The tissues from the Wisconsin cattle did not include sections from the uterine body near the point of bifurcation. As noted previously, abnormalities were sometimes present in this part of the uterus in the Beltsville cattle when they were not detected in the upper part of the uterine horn. The number of blocks of tissue per animal which were available for study was also less in the Wisconsin than in the Beltsville cattle. It is thus possible that some abnormalities escaped detection in the Wisconsin tissue. Furthermore, the poor-breeder group in the Wisconsin series did not include any poor breeding heifers. Twelve of 15 poor breeding heifers (80%) among the Beltsville cattle showed some type of abnormality. On the other hand, the difference between these two populations regarding endometrial abnormalities may be a real one and the two groups are discussed separately for that reason.

When the data from both groups of cattle are combined 29 of the 77 animals showed at least one type of abnormality in the endometrium. Abnormalities were found in six of the 37 good breeders (16%) and in 23 of the 40 poor breeders (57%). By combining these two groups there is no change in the frequency of abnormalities among the good breeders (16%) but there is a reduction in the frequency from 70% for the Beltsville group alone to 57% when these were combined with the Wisconsin group. The occurrence of encapsulated glands, irrespective of whether or not other abnormalities were also present, was found in 18 out of 40 animals with breeding difficulties (45%) and in three out of 37 animals with good breeding records (8%). This treatment of the data also suggests an association between breeding difficulty and the presence of these endometrial abnormalities but such a suggestion must be accepted with considerable reservation in view of the difference seen between the two groups of cattle. The significance of the abnormalities which have been found, therefore, remains doubtful.

Lymphoid nodules, although often present in other tissues do not occur regularly in the stroma of the bovine endometrium, and were found in the endometria of only two of 37 apparently normal breeding animals which we have examined. However, they were present in the endometria of nine out of 40 poor breeders. When nodules were present they were usually seen on all blocks of tissues and very often several of them (in one instance as many as eight) were seen on a single section.

This would indicate that nodules are widely distributed when present. Their presence, however, did not appear to interefere with normal pregnancy up to the 36th day since apparently normal embryos were found in seven of the nine animals in which nodules were found and which had been bred during the cycle previous to slaughter.

Hallman (1919), Miller (1950), Simon (1951), Brus (1954), and Kampelmacher (1954) have concluded that the abnormalities which they have described were the result of an infection. Indeed, a general inflammatory reaction was present in the tissue. However, in the animals on which the present report is based a general inflammatory reaction was not evident. Hence, although a previous low-grade infection may have caused these alterations, the possibility must also be considered that these abnormalities were the result of some other disturbance such as a deranged endocrine system.

Cystic endometrial glands were produced with estrogenic hormones in the guinea pig by Nelson (1939) and in the hamster by Bacon (1951) and are present in endometria of cows with cystic ovaries. Changes in the endometrial stroma were produced with estrogens in the rat by Burack (1942) and in the Macaque by Pfeiffer and Hooker (1944). Endometrial hyperplasia and cystic uterine glands are also a well described pathological condition in the human and are associated with unripened and cystic ovarian follicles and hence with a failure in ovulation. The hyperplastic condition of the endometrium in the human is also attributed to a continual excessive supply of estrogens (Ogilvie, 1951). However, the ovaries of these cows exhibiting either cystic or encapsulated endometrial glands were normal. Furthermore, the fact that in two animals with cystic and seven animals with encapsulated glands normal embryos were recovered as late as the 36th day of pregnancy indicated that these animals not only ovulated but were also capable of a normal course of pregnancy, at least up to 36 days. The data indicate that if reproductive difficulties are encountered as a result of the occurrence of endometrial abnormalities of the type described, they occur later than the 36th day of pregnancy.

Summary

Two types of glandular abnormality and nodules of lymphoid tissue in the bovine endometrium have been described.

These abnormalities appeared more frequently in the endometrium of cattle with a poor reproductive history than in apparently normal cattle. In two separate populations of cows from widely separate locations,

however, this relationship was only evident in one of the groups and not in the other. In view of this observation, the suggestion that these abnormalities may be associated with poor reproductive performance must be taken with reservations. A search for these and possibly other types of abnormalities and a determination of their relationship to reproductive perfcrmance on a wider scale than has been done to date could possibly add useful information to our knowledge of abnormal reproductive performance.

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THE EFFECT OF AGE AND PLANE OF NUTRITION ON GROWTH HORMONE AND THYROTROPIC HORMONE CONTENT OF PITUITARY GLANDS OF HOLSTEIN HEIFERS [1]

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THE importance of the anterior pituitary gland in the regulation of growth of animals has been well established, but the relative importance of the various pituitary hormones in this regulation is less well understood. Several attempts have been made to associate growth rates in farm animals with the rates of secretion of the growth and thyrotropic hormones.

Baird *et al.* (1952) reported greater amounts of growth hormone in the pituitary glands of swine of a rapidly growing line than in those of a slowly growing line. In both lines, amounts of growth hormone per unit of body weight increased during the period of most rapid growth, and decreased as "maturity" (approximately 225 lb.) was approached. Clegg and Cole (1954) detected greater amounts of growth hormone in the pituitaries of beef heifers whose rate of gain had been increased by implantation with stilbestrol, than in those of untreated heifers. However, the pituitaries of stilbestrol-treated steers, whose rates of growth were considerably greater than the treated heifers, did not contain significantly different amounts of growth hormone than those of untreated steers. Fransen and Andrews (1954), studying various physiological aspects of dwarfism in beef calves, reported normal levels of both growth hormone and thyrotropin in their pituitaries. Marlowe and Chambers (1954) failed to detect any significant differences in thyrotropin content of pituitaries of dwarf and normal Hereford and Angus calves, but found greater amounts of growth hormone in the pituitaries of dwarf calves than in those of normal calves. Elijah and Turner (1942) reported a definite rise in the thyrotropin concentration of pituitaries of swine during the period of most rapid growth, and a decrease in concentration in older, more slowly growing swine. Perry *et al.* (1951) detected greater pituitary contents of thyrotropin in swine whose growth rates had been increased by thyroprotein feeding. Turman

[1] Supported in part by funds from the regional project N.E.–1 entitled "Causes and Prevention of Reproductive Failures in Dairy Cattle", a cooperative study by agricultural experiment stations in the northeastern region and the Dairy Husbandry Research Branch U.S.D.A.

and Andrews (1955) reported higher pituitary thyrotropin in swine whose efficiency of gain had been increased by growth hormone injections.

In the studies reported here, biological assays were carried out on the pituitaries of Holstein heifers raised on three levels of nutrition, in an attempt to relate differences in growth rates to growth hormone and thyrotropin production.

Experimental Procedure

Pituitary glands were collected from 72 Holstein heifers, fed on three levels of nutrition and slaughtered at six different ages. Twenty-four heifers were allotted at random to each plane of nutrition, hereafter referred to as "low", "medium", and "high" planes. These levels of nutrient intake were approximately 60, 100 and 140% respectively, of the total digestible nutrients recommended for growing dairy heifers by Morrison (1950). Complete records of feed intake and rates of growth and development were kept for the duration of the feeding period, and have been reported by Sorensen (1953). Twelve heifers (4 on each level of nutrition) were slaughtered at each of the following weeks of age: 0 to 1, 16, 32, 48, 64 and 80.

The pituitaries were weighed, the anterior and posterior lobes separated, and frozen within one hour after slaughter. The hypophysectomized rat tibia test, as described by Greenspan *et al.* (1949) was the assay procedure used to estimate the growth hormone potency of the anterior lobes. Eight groups of hypophysectomized rats were used in assaying the pituitaries, and where possible, pituitaries from all three levels of nutrition at a given age were included in each group. As the rats became available, the anterior lobes were thawed, weighed, and individually homogenized in 0.85% physiological saline solution in a Potter-Elvehjem type tissue homogenizer equipped with a Teflon pestle. For the first lot of ten pituitaries which were extracted, 8 ml. of saline were used, 0.5 ml. of this extract or one-sixteenth of the total extract being injected daily per rat. Since epiphyseal cartilage widths of these rats lay in the upper portion of the standard curve, 10 ml. of saline were used in all subsequent extractions, so that one-twentieth of the total extract was injected per day. After homogenization, the resulting suspension was centrifuged for 15 minutes at $850 \times g$ and the supernatant fluid refrigerated at 2° C. until used for the bioassay.

Two rats were used in the assay of each pituitary, giving 8 observations for each plane of nutrition at each slaughter age. The extracts were administered by subcutaneous injection daily for four days.

Twenty-four hours after the last injection the rats were sacrificed, and the tibiae and thyroids removed. The thyroids were fixed in Bouin's solution and sectioned for histological study. The tibiae were separated from the soft tissue, split mid-sagittally with a sharp razor blade, and stained according to the procedure of Evans *et al.* (1943).

The growth hormone contents of the pituitary extracts were estimated by measuring the average widths of the uncalcified epiphyseal cartilages of the tibiae. The average widths of the cartilages of the rats injected with each pituitary extract were then compared with a standard dose-response curve. The standard curve was established by injecting graded amounts of a purified growth hormone preparation [2] into hypophysectomized rats and plotting the average response in cartilage width against the logarithm of the daily dose. Standards were administered in the same manner as pituitary extracts, seven rats being used for each dose level.

In order to estimate the thyrotropin content of pituitary extracts, sections of thyroid glands of injected rats were examined microscopically. Hypophysectomy in rats causes a regression of thyroid acinar epithelial cells from a normal cuboidal or low columnar type, to a flattened, squamous type of cell. Replacement therapy with pituitary extract causes these cells to increase in height as a result of the thyrotropin present in the extract (Smith, 1930). This principle was used by Hertz and Oastler (1936) as a method of thyrotropin assay, and was the method used in this experiment. Acinar epithelial cell heights were measured under a microscope at a magnification of 440× using a calibrated micrometer eyepiece. Two cells were measured in each of five acini, in each of three sections, making a total of thirty measurements per rat, or 60 measurements per heifer. The average height of these 60 epithelial cells was used as an estimate of thyrotropin content of the heifer's pituitary when compared with the average cell height of untreated hypophysectomized rats.

Results

A linear relationship was found to exist between tibial epiphyseal cartilage widths and the logarithms of the daily dosages of purified growth hormone when levels of between 0.02 and 0.50 mg. per day were administered to hypophysectomized rats. This relationship, which gave an index of precision of 0.1499 when analyzed statistically by the

[2] Kindly supplied by Dr. Irby Bunding. The Armour Laboratories, Chicago, Illinois. Lot No. R491017.

method of Bliss (1952), is illustrated in figure 1. Epiphyseal cartilage widths of rats injected with pituitary extracts were compared with this standard curve in order to estimate the approximate growth hormone potency of each gland.

In five instances, the cartilage widths were slightly greater than the upper fiducial limit of the standard curve at the highest level of purified

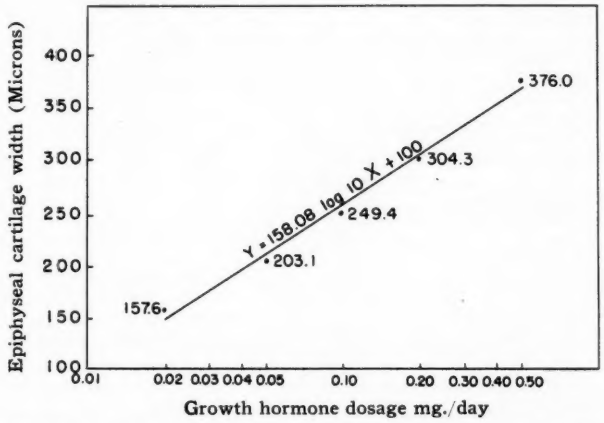

Figure 1. Log dose—response curve for standard growth hormone treatments using tibia test.

growth hormone injection. This upper value, of 0.50 mg. per day, was taken as the growth hormone content of the injected extracts in these cases.

No significant differences were detected in the total growth hormone content of the pituitaries as a result of level of nutrition or age at slaughter. However, when these values were expressed as concentration of hormone per gram of anterior lobe, differences between ages became statistically significant ($P<0.05$). When expressed per 100 lb. of body weight, these differences were still more pronounced, and became highly significant ($P<0.01$). Average growth hormone contents per gram of gland and per 100 lb. of body weight at each slaughter age are shown in table 1, and it will be noted in both cases that hormone levels are higher in the younger animals and decrease with increasing age. In neither case were there any significant differences detected as a result of plane of nutrition.

In order to determine whether there was any relationship between growth hormone levels and rates at which heifers were growing at the time of slaughter, the percentage of the weight of each animal at slaughter which was gained during the 16-week period immediately prior to slaughter was calculated. The percentage increase in height at

TABLE 1. PITUITARY GROWTH AND THYROTROPIC HORMONE CONTENTS, RELATIVE THYROID WEIGHTS, AND GROWTH RATES OF HEIFERS RAISED IN THREE PLANES OF NUTRITION AND SLAUGHTERED AT VARIOUS AGES

Items	Weeks of age at slaughter					
	0–1	16	32	48	64	80
Mean pituitary growth hormone content per gm. anterior lobe (mg.) *	11.64 (6.72)[a]	11.66 (4.24)	10.98 (4.12)	8.18 (3.85)	6.98 (3.60)	7.73 (3.66)
Mean pituitary growth hormone content per 100 lb. body wt. (mg.) **	6.67 (4.51)	3.07 (1.17)	2.06 (0.78)	1.17 (0.55)	0.94 (0.45)	0.93 (0.55)
Mean thyroid acinar cell height of rats injected with pituitary extracts (Micra) *	8.50 (1.30)	8.12 (1.20)	8.24 (0.75)	7.94 (0.31)	7.42 (0.58)	7.41 (0.65)
Mean thyroid weight of heifers per 100 lb. body wt. (gm.) **	22.28 (23.28) 15.75 (5.82)[b]	7.15 (4.21)	4.24 (1.34)	4.11 (1.90)	3.93 (2.58)	2.17 (0.38)
Mean percentage of body weight at slaughter which was gained by heifers during 16 wk. prior to slaughter **		56.1 (11.49)	42.2 (6.02)	29.9 (3.85)	22.9 (2.20)	15.4 (2.37)
Mean percentage of height at withers at slaughter which was gained by heifers during 16 wk. prior to slaughter **		15.05 (8.23)	12.71 (2.46)	9.31 (2.14)	5.68 (2.44)	4.35 (1.41)

* Differences between means statistically significant ($P<0.05$).
** Differences between means statistically highly significant ($P<0.01$).
[a] Standard deviation.
[b] Mean and standard deviation, omitting value for heifer No. 10, which had an extremely enlarged thyroid (94.08 gm. per 100 lb. body weight).

withers was calculated in a similar manner. The averages for both these values are given in table 1. The relative rates of growth of heifers were found to be positively correlated ($P<0.01$) with the growth hormone contents of their pituitaries, whether expressed in milligrams per gram of anterior lobe or in milligrams per 100 lb. of body weight. The correlation coefficients with their confidence limits are shown in table 2.

The results of the thyrotropic hormone assay, based upon stimulation of the thyroid acinar epithelia of hypophysectomized rats by injected pituitary extracts, are shown in table 1. Differences due to age were

statistically significant ($P<0.05$), amounts being highest in the youngest animals and decreasing with increasing age. A positive correlation ($P<0.01$) was found to exist between thyrotropin activities and rates of growth of the heifers during the 16-week periods prior to slaughter, as indicated in table 2.

Unlike the growth hormone results, there was a definite tendency toward higher pituitary thyrotropin activity with higher planes of

TABLE 2. COEFFICIENTS OF CORRELATION BETWEEN PITUITARY GROWTH HORMONE AND THYROTROPIC HORMONE CONTENTS AND RELATIVE RATES OF GROWTH OF HEIFERS, BASED ON PERCENTAGE OF BODY WEIGHT AND HEIGHT AT SLAUGHTER WHICH WAS GAINED DURING THE SIXTEEN WEEK PERIOD PRIOR TO SLAUGHTER

	Percentage increase during sixteen weeks immediately prior to slaughter in:	
	Body weight	Height at withers
Growth hormone per gram anterior pituitary	.37 (.13—.57)*	.42 (.19—.61)
Growth hormone per hundred pounds of body weight	.66 (.50—.79)	.54 (.33—.70)
Thyroid acinar cell height of injected rats	.45 (.22—.63)	.46 (.23—.64)

* Confidence limits ($P<0.05$).

nutrition. Mean thyroid acinar cell heights of 7.61 micra, 7.72 micra, and 8.15 micra were obtained for rats injected with pituitary extracts from heifers on low, medium, and high planes of nutrition respectively. These differences fell only slightly short of statistical significance (F value necessary for significance at the 5% level=3.21; F value obtained=3.16).

In an attempt to determine whether or not the thyrotropic hormone content of the pituitaries was indicative of the actual rate at which the hormone was being secreted, thyroid weights of all heifers were expressed in grams per 100 lb. of body weight. Table 1 includes the mean thyroid weights per 100 lb. of body weight of heifers slaughtered at each age, and these differences were found to be statistically highly significant ($P<0.01$). Differences between levels of nutrition were significant ($P<0.05$) with mean values of 5.27, 4.38, and 3.31 gm. being attained for the low, medium and high planes of nutrition respectively. These relative thyroid weights were positively correlated with thyroid acinar cell heights of rats injected with pituitary extracts

from the heifers ($r=0.60$, $P<0.01$). This relationship is illustrated in the photomicrographs in figure 2. Figure 2A illustrates the thyroid atrophy that occurs after hypophysectomy. Figure 2B illustrates the increased epithelial cell height seen after injection of pituitary extract of a week-old heifer with a normal thyroid. Figure 2C shows excessive

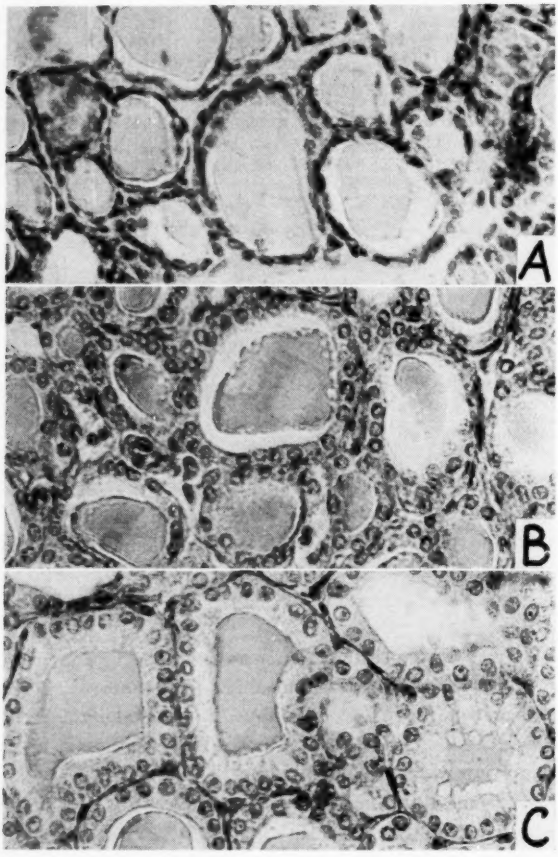

Figure 2. Photomicrographs of thyroids of rats 15 days after hypophysectomy (440 ×). (A) No replacement therapy. (B) Injected for 4 days with anterior pituitary extract from a week-old heifer having a normal thyroid (11 gm.). (C) Injected for 4 days with anterior pituitary extract from a week-old heifer having a greatly enlarged thyroid (67 gm.).

stimulation of the acinar epithelium after injection of pituitary extract of a heifer with an enlarged thyroid.

Discussion

Before drawing definite conclusions from the foregoing results, some of the limitations of biological assays of this kind should be considered. Crude pituitary extracts contain a number of different hormones and one may expect various synergisms and antagonisms which might not be obtained if the pure hormones were used separately. Further, it is difficult to be certain that the quantity of hormone detected in a given pituitary is actually a measure of the rate at which the gland was secreting the hormone at the time the animal was slaughtered. It might merely represent the amount of hormone being stored in the gland, or the residual hormone remaining after secretion has taken place.

The high correlation found between growth hormone per 100 lb. of body weight and growth rates of the heifers prior to slaughter suggests that the growth hormone content of the pituitary reflects the actual rate of secretion. The greater amounts of growth hormone available per unit of body tissue may be an important factor responsible for the faster rates of growth in the younger animals.

These results are in agreement with those reported for swine by Baird *et al.* (1952), and support their contention that as an animal grows older and larger, there is less growth hormone available per unit of tissue, which results in a decreasing growth rate as the animal approaches maturity.

The fact that there were no significant differences in growth hormone levels in the heifers due to plane of nutrition indicates that the more rapid rates of growth of heifers on the higher levels of nutrition were not the result of increased growth hormone production by the pituitary. Other factors such as increased amounts of nutrients available for growth appear to be responsible for the faster growth rates of the heifers on the higher planes of nutrition. The fact that growth hormone levels in the pituitary per 100 lb. of body weight were not influenced by plane of nutrition and were highly correlated with relative growth rates suggests that a measure of growth hormone secretion rates in live animals might have some value in predicting subsequent performance insofar as rate of gain is concerned.

There is fairly good evidence that the actual rate of secretion of thyrotropin was being measured, since the thyroid epithelial heights of injected rats were found to be highly correlated with the thyroid

weights per 100 lb. of body weight of the heifers at the time of slaughter. In addition, the high correlation between thyrotropin content of the pituitary and rate of body growth of heifers prior to slaughter indicates that this hormone may also be one of the factors responsible for different rates of growth of these heifers at different ages.

Although differences in total thyrotropin content of the pituitaries of heifers on the different planes of nutrition fell just short of statistical significance at the 5% level, there was a definite tendency towards greater amounts in the heifers on the high plane, and smaller amounts in those on the low plane of nutrition. These results do not seem to be in accord with the significantly greater thyroid weights per 100 lb. of body weight of the heifers on the low plane of nutrition and smaller thyroid weight per 100 lb. of body weight of those on the high plane. However, if the thyrotropin contents of the anterior pituitaries could be expressed in terms of body weight, this trend would probably be reversed due to the considerably higher body weights of the heifers on the high plane of nutrition and lower body weights of those on the low plane. This inverse relationship between thyrotropin production per unit of body weight and level of nutrition would then explain the greater relative thyroid weights of the heifers on the low plane of nutrition, and the smaller weights of those on the high plane.

Summary

Bioassays were carried out on anterior pituitaries of Holstein heifers raised on 3 levels of nutrition and slaughtered at 6 different ages to determine their growth hormone and thyrotropic hormone contents. Growth hormone per gram of anterior pituitary, growth hormone per 100 lb. of body weight and total thyrotropic hormone were greater in the younger heifers and gradually decreased with increasing age. No significant differences in any of these measurements could be detected due to plane of nutrition, although differences in total thyrotropin came very close to significance ($P<0.05$), the levels being highest in the heifers on the high plane of nutrition and lowest in heifers on the low plane.

Rates of body growth during the 16-week periods immediately prior to slaughter were found to be positively correlated with growth hormone per gram of anterior pituitary, growth hormone per 100 lb. body weight, and total thyrotropin content of pituitaries. Thyrotropin contents were

also positively correlated with relative thyroid weights of the heifers from which the pituitaries were taken.

These results have been interpreted as indicating that the quantities of growth hormone and thyrotropin detected in pituitary assays are fairly close approximations of the actual rates of secretion of these hormones by the pituitary. They suggest that differences in rates of growth of heifers at different ages are at least partly due to differences in amounts of pituitary growth hormone and thyrotropin being produced, but that differences in growth rates of heifers on different feeding levels are due to differences in amounts of nutrients available for growth, rather than to any differences in hormone production by the pituitary.

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THE HORMONAL CONTROL OF ESTRUS AND OVULATION IN THE BEEF HEIFER

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THE purpose of this project was to determine whether a synchronization of estrus and ovulation could be obtained in a group of beef heifers by limited hormonal injections.

The methods described to date for controlling estrus and ovulation in cattle have practical disadvantages. The use of gonadotropins alone necessitates an accurate knowledge of the individual estrous cycle, and fertility results only when injections are made during the follicular stage of the cycle or after removal of an existing corpus luteum. The number of ovulations induced by this means cannot as yet be controlled with certainty, an undesirable feature when multiple pregnancies often terminate in abortion. The removal of the corpus luteum, as a means of synchronizing estrus and ovulation, requires a certain amount of skill not usually found outside of research institutes and at best can apply to about 25% of a breeding herd. It would seem that progesterone controlled estrus and ovulation offers the greatest promise of success. Its effect is not of a stimulatory nature, since at proper dosage level follicular growth only occurs after the inhibitory effect has worn off, a condition similar to the decline of the corpus luteum in the normal cycle.

Daily injections of progesterone in oil have been shown by Dutt and Casida (1948), Ulberg *et al.* (1951a), and Christian and Casida (1948) to inhibit estrus and ovulation in the ewe, gilt, and in the cow, respectively. Estrus occurred in the cow 5–6 days after cessation of daily injections of 50 mg. of progesterone. A conception rate of 50% was reported by Willet (1951) when dairy heifers were inseminated at the progesterone controlled estrus, whereas Trimberger and Hansel (1955) found that only 3 of 24 progesterone treated dairy cows conceived at first service following insemination at the post-injection estrus.

Daily injections of progesterone in oil were used in order to effect an inhibitory level of circulating hormone. A routine involving daily injections is not practical in range stock. One of the prime considerations

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in the present study was to perfect a means whereby a prolonged inhibition, of constant duration, could be induced by a single progesterone treatment.

Materials and Methods

Twenty 14–16 month old heifers, weighing between 390 and 540 lb. were placed on experiment March 10, 1953 to determine the normal range of estrous cycle length in the type of animal used in these trials. Twice daily checks were made with vasectomized bulls. A heifer was considered in heat when she would stand to be mounted by a bull or another heifer. This trial was conducted through January 1954.

The influence of crystalline progesterone was tested in various groups of Hereford heifers, between the ages of 14 to 30 months and weighing from 1500–1200 lb.

Crystalline progesterone implants were used to supply the surface area weight ratio needed for prolonged progesterone exposure to the tissues. Crystalline progesterone was finely ground in a hand homogenizer with a 0.3% starch emulsion to a final concentration of 70 mg. per ml. The purpose of the starch emulsion was to prevent the settling out of the macrocrystals in order to facilitate transfer and to insure uniform dosage from one injection to the next. This did serve the purpose, for a gentle shaking of the preparation resulted in progesterone crystals being suspended for an ample time to allow withdrawal from the container and injection without settling out. No attempt was made to correlate progesterone crystal size and absorption rate, although different preparations of the progesterone in starch emulsion, at the same concentration of hormone, did exhibit different inhibitory periods. This preparation was injected at a single treatment subcutaneously in the shoulder region. Various dosages were obtained by varying the volume injected rather than the concentration of hormone.

In the trials conducted, involving 179 heifers, 72 heifers were under close surveillance. The heifers were checked at least twice daily with vasectomized bulls and, as with the control heifers mentioned above, were not considered in heat unless they would stand to be mounted. With the exception of those specified in the text, heifers were not placed on trial unless the estrous cycle preceding that of treatment was of normal length (17 to 24 days). Daily rectal palpations were not taken, but numerous palpations were made as needed to determine the status of follicular growth.

A single subcutaneous injection of progesterone in starch emulsion was

administered to 57 heifers at various stages of the estrous cycle. Two hormonal injections were made in 122 of the heifers treated; that is, the initial injection of progesterone was followed 15 days later by a single subcutaneous injection of equine gonadotrophin. The equine gonadotrophin was prepared in this laboratory according to the acetone fractionation procedure as described by Goss and Cole (1940) and averaged 900 I.U. per mg.

TABLE 1. ESTROUS CYCLE LENGTHS OF YEARLING HEREFORD HEIFERS [a]

March through December, 1953

Heifer No.	Length of consecutive estrous cycles in days															Average (days)
1	20	19	19	19	19	21	19	20	21	19	19	19	20			19.5
2					22	20	18	17	20	20	22	20	20	19	18	19.6
3		19	19	18	19	21	19	23	18	20	20	19	19	21		19.6
4						20	20	23	20	20	18	19	21			20.1
5		17	18	24	22	22	21	22	23	24	23	22	23	23		21.9
6					17	16	23	20	24	22	21	21	22	21	23	20.9
7					20	19	22	18	21	21	22	19	19			20.1
8							23	22	22	20	22	21	21	23	26	22.2
9					18	18	18	18	17	18	18	17	19	18		17.9
10				19	19		14	19	20	21	18	19	21	19		18.9
11					18	19	19	19	19	21	19	20	19	19		19.2
12				17		21	22	20	19	21	21	18	22	19	19	19.9
13				20	18	21	20	21	19	22	21	19	21	22		20.4
14					20	17	21	18	20	20	20	18	18	19	19	19.1
15				19	21	19	20	22	18	23	20	20	19	21		20.2
16					22	21	19	20	21	22	23	24	23			21.6
17				22	19	23	19	22	22	22	20	22	22	18		21.0
18					20	20	19	19	20	20	21	19	19	18		19.5
19								18	19	21	22	21	19	20	19	19.9
20				21	20	19	21	22	18	20	22	19	18	20		20.0

[a] Estrous cycle lengths ranged from 14–26 days with a group average of 20.1±.12 days.

Results and Discussion

Estrous Cycle Length in Nontreated Heifers

The range in estrous cycle length was 14–26 days with a group average of 20.1±.12 days (table 1). There was one cycle of 14 days duration, one of 16, seven of 17, twenty-seven of 18, fifty-four of 19, thirty-nine of 20, thirty-three of 21, twenty-nine of 22, fourteen of 23, four of 24 and one of 26. Heifer 10 showed the shortest cycle length encountered, 14 days. This animal, however, had been subjected to experimental surgery six weeks earlier and had not shown any estrous activity for 35 days preceding this short cycle.

The heifers were from 14 to 16 months of age when placed on trial March 10, 1953. Although this is an age usually considered as sexually mature in the beef breed, all of the heifers did not show estrous activity

until August 9, when Heifer 19 came in heat for the first time. The heifers weighed between 390 and 540 lb. at the start of the trial and from 820 to 1020 lb. at the end of the trial, 15 of the 20 grading "choice" at slaughter. Once expressed, estrus occurred at regular intervals throughout the trial in all heifers except No. 12, regardless of age or degree of finish.

TABLE 2. THE EFFECTS OF VARIOUS DOSAGES OF PROGESTERONE IMPLANTS ON THE ESTROUS CYCLE OF FEEDER HEIFERS [a]

Heifer No.	Dosage	Day of cycle injected	Days from injection to estrus	Days from day–1 to estrus	Succeeding cycle length (days)
	mg.				
878	540	14	44	57	18
804	540	6	17	22	23
807	540	4	17	20	20
863	540	6	19	24	5
883	540	17	17	33	21
818	540	15	18	32	9
803	770	15	17	31	20
815	1120	12	17	28	Preg.
877	1120	8	16	23	Preg.
864	1120	11	19	29	22
807	1120	11	20	30	17
819	1120	11	35	45	11
883	1120	11	43	53	..
864 [b]	1120	11	22	32	..
807 [b]	1120	11	23	33	..
819 [b]	1120	11	23	33	..
883 [b]	1120	11	35	45	..

[a] Heifers weighing on the average 550 lb. at the start of experiment.
[b] Treated again on a succeeding cycle.

Effect of Progesterone Alone on Estrus and Ovulation

The first two groups of heifers treated were "feeder heifers" weighing about 560 lb. and were in good breeding condition, whereas the third group was composed of animals that had been receiving concentrate and roughage for 10 months (table 1) and were in an over-finished condition. The latter group graded "choice" at the time of treatment, a condition generally considered as too fat for breeding stock. For this reason the results of progesterone treatment of these animals will be considered separately.

The results in table 2 show the effect of different dosages of crystalline progesterone (540–1120 mg.) injected at various stages of the estrous cycle in the "feeder heifers". In the 17 cycles studied on 11 heifers

estrus occurred 17–44 days after the single injection of progesterone. Estrus was synchronized within a 3-day range, 17–19 days after the progesterone injection in 6 of 7 heifers receiving 540–770 mg. of hormone, whereas the range of post-injection estrus was 16–23 days in 5 of 10 heifers receiving 1120 mg. of progesterone.

TABLE 3. FURTHER DATA ON THE EFFECT OF PROGESTERONE ON ESTRUS AND OVULATION IN FEEDER HEIFERS [a]

Heifer No.	Dosage	Day of cycle treated	Days from inject. to estrus	Days from day–1 to estrus	Ovulated at post-inject. estrus
	mg.				
66	560	2	25	26	—
81	560	6	17	22	+
6	560	9	16	24	+
144	560	9	18	26	+
38	560	14	17	30	+
127	700	4	18	23	+
145	700	5	15–18 [b]	19	+
134	700	6	—	—	—
129	700	7	20	26	+
128	700	9	—	—	—
143	700	11	16	26	+

[a] Heifers weighing on the average 600 lb.
[b] Stayed in estrus 4 days.

Heifers 815 and 877 were injected on day-12 and day-8 of the estrous cycle, and were inseminated when they came in heat 17 and 16 days respectively post-progesterone injection. Autopsy 37 days post-insemination demonstrated both heifers to be pregnant, each carrying a normal fetus of crown-rump length, 1.2 cm.

Autopsy of 3 heifers (table 2) re-treated on a succeeding cycle demonstrated that heifers 864 and 807 had recently ovulated whereas one heifer, 819, had a large follicle in one ovary. Heifer 883, an animal which had responded at 540 mg. of progesterone, did not ovulate the large follicle present 20–24 days post-progesterone injection (1120 mg.). This follicle regressed and was replaced by another large follicle 35 days after injection.

Although the estrous behavior was normal and pregnancy resulted when two heifers were inseminated at the progesterone controlled estrus, the short succeeding estrous cycles encountered in some of the treated heifers (table 2, column 6) suggested that ovulation might not have occurred following estrus. To determine this 11 heifers (table 3) were

treated the same day with a single injection of 560 or 700 mg. of progesterone suspension. Eight of these heifers came in heat within a 6-day range of each other, 15–20 days post-injection. At the lower dosage level of 560 mg. of progesterone, 4 of 5 heifers came in heat within a 3-day range while at the higher dosage level 4 out of 6 heifers showed a 6-day range in estrous activity. Ovarian activity was followed by rectal palpation from the day of heat until 2 days after the end of heat. All of the heifers designated by a plus (column 6 of table 3)

TABLE 4. THE EFFECTS OF PROGESTERONE IMPLANTS ON THE ESTROUS CYCLE OF FAT HEIFERS [a]

Heifer No.	Dosage	Day of cycle injected	Days from injection to estrus	Days from day–1 to estrus
	mg.			
19	1120	11	19	29
7	1120	11	47	57
4	1120	11	32	42
11	1120	11	34	44
5	1120	11	29	38
18	1120	11	33	43
7 [b]	1120	2	40	42
4 [b]	1120	11	32	42
11 [b]	1120	11	—	—
5 [b]	1220	11	—	—
18 [b]	1120	1	—	—

[a] Heifers weighing 850–1200 lb.
[b] Heifers treated again on a succeeding cycle.

ovulated within 2 days from the start of estrus, with one exception. Heifer 145, an animal in heat 4 days, ovulated on the third day from the start of estrus. Ovulation occurred in 8 of the 9 heifers showing estrus. It is noted that the estrus shown by heifer 66, the only heifer coming in heat but not ovulating the large follicle present in the ovary, did not occur until 25 days after injection.

The results of the study on "fat heifers" (table 4) showed that a synchronization of estrus could not be obtained with 1120 mg. of progesterone. All signs of estrus were prevented for 19 days after the progesterone injection at which time one heifer came into heat (Heifer 19). The remainder of the group came in heat 29–47 days after the progesterone injection. Rectal palpation 7–11 days after progesterone injection, a time at which the heifers would have normally come into heat if not treated, showed follicular growth to be at a minimum (follicles less than 1 cm.). All of the heifers showed vulvar hyperemia,

mucous discharge from the vagina, evidence of mammary stimulation and some evidence of estrus 18–20 days after injection. No. 19, however, was the only heifer that would stand for service at this time and as rectal palpation and autopsy demonstrated, was the only one of the group to ovulate. Re-treatment of the heifers not showing heat indicated the same response. Although estrus and ovulation were inhibited in this group for at least 19 days after progesterone injection, with synchronization of follicular growth, only one heifer came in heat and ovulated at that time.

In view of the fact that 1120 mg. of progesterone did result in the synchronization of estrus and ovulation in the lighter heifers in table 2, it would seem that the failure of ovulation in the fat heifers was not due to excessive exogenous progesterone. On the other hand the ovarian condition found in this treated group is not compatible with that described by Ulberg *et al.* (1951b) in dairy cattle receiving daily injections of progesterone below that necessary to inhibit heat and follicular growth. These workers reported that while 50 mg. of progesterone daily would inhibit estrus and follicular growth, 25 mg. daily, while inhibiting estrus, would permit follicular growth to continue. With the fat heifers, however, follicular growth was shown by rectal palpation to be at a minimum 1–10 days following injection and the large follicle, not ovulating 19–20 days post injection, presumably developed subsequent to exogenous progesterone inhibition.

It would seem from the results with the progesterone alone that 560 mg. in a single injection was more capable of synchronizing estrus and ovulation within a limited range than 700 or 1120 mg.

The Effect of Progesterone Followed by Gonadotrophin Injection on the Estrous Cycle of Heifers

In view of the results cited above, namely that although inhibition and follicular synchronization were realized by a single injection of progesterone estrus and ovulation did not invariably result, a sequence of hormonal treatment was introduced. A group of "feeder heifers" weighing approximately 650 lb. was injected the same day with 560 mg. of progesterone suspension, and in 19 of the 20 heifers this was followed 15 days later by a single injection of 2140 I.U. of equine gonadotrophin (table 5). It was reasoned that equine gonadotrophin, a substance known to induce ovulation during the follicular stage of the estrous cycle, might insure ovulation of the ripe follicles developing subsequent to progesterone inhibition. As noted in table 5, the injection of progesterone was

given at various stages of the estrous cycle (day-3 to day-21). Estrous activity was not detected in any of this group until 15 days after the progesterone injection, at which time heifer 137 came in estrus. Autopsy two days postestrus showed that this heifer, under the influence of progesterone alone, had recently ovulated. The remaining 19 heifers were in-

TABLE 5. THE EFFECTS OF PROGESTERONE AND GONADOTROPHIN ON ESTRUS IN MATURE HEIFERS

Heifer No.	Day of cycle progesterone injection [a]	Day of cycle gonadotrophin injection [b]	Days from injection to heat [c]	Days from day–1 to estrus
136	3	18	18	20
67	3	18	19	21
102	4	19	19	22
28	7	22	—	—
128	8	23	17	24
33	9	24	17	25
59	9	24	17	25
48	11	26	16	26
133	12	27	16	27
20	12	27	16	27
137	13	—	15	27
66	14	29	18	31
81	15	30	—	—
6	15	30	18	32
127	16	31	18	33
130	16	31	19	34
135	16	31	—	—
143	20	35	16	35
134	20	35	19	38
64	21	36	16	36

[a] 560 mg. progesterone.
[b] 2140 I.U. Equine Gonadotrophin.
[c] Days from the progesterone injection to heat.

jected with gonadotrophin 15 days post-progesterone injection and as shown by column 4 of table 5, 16 of the 19 heifers came into estrus 1–4 days after the gonadotrophin injection. Of the 16 heifers showing estrus, 5 came in heat 16 days post-progesterone injection or one day post-gonadotrophin injection; 3 came in heat 17 days post-progesterone injection or 2 days post-gonadotrophin injection; 4 came in heat 19 days post-progesterone or 3 days post-gonadotrophin injection and 4 came in heat 19 days post-progesterone injection or 4 days post-gonadotrophin injection. The 3 heifers not showing estrus (heifers 28, 81 and 135) were autopsied 6 days following the gonadotrophin injection. Two of these had a large follicle in one ovary and the third heifer (81) had

super-ovulated, 10 recent ovulation points being found in the one ovary and 5 in the other. Two heifers (heifers 48 and 33) showing estrus following treatment were autopsied 2 and 4 days, respectively, post-estrus. Both of these heifers had recently ovulated.

The remaining 14 heifers were inseminated 20–24 hours from the start of estrus and were autopsied, on the average, 27 days after insemination. To test the accuracy of insemination, 6 non-treated heifers were inseminated following estrus and autopsied 27 days after insemination. In the control group 4 of the 6 heifers were found to be pregnant at autopsy. Only 2 of the 14 treated heifers were pregnant, heifer 67 carrying 3 normal fetuses and heifer 147 carrying one normal fetus. Although the other treated heifers had not conceived, at least 6 were found to have 2 or 3 large corpora lutea in their ovaries.

The multiple ovulations encountered with 2140 I.U. of equine gonadotrophin described an excessive rather than facilitory dosage. For this reason the gonadotrophin dosage was reduced in later trials.

In a later trial 35 Hereford heifers, weighing about 650 lb. each, were injected on the same day with 560 mg. of progesterone suspension followed 15 days later with a single injection of 750 I.U. of equine gonadotrophin. Although it was determined by rectal palpation that none of this group was pregnant at the start of the trial, there was no information available on previous estrous activity.[3] Thirty-one heifers were observed in heat within a four hour period, one day following the gonadotrophin injection, and the whole group was inseminated 48 hours after the gonadotrophin injection. The heifers were inseminated with poor quality Hereford semen from the cooperator's own bull, at his request, and turned out to pasture with an Angus bull. The number of pregnancies obtained by the treatment described is not known.

This same procedure was carried out in another trial with 24 Hereford heifers where again nothing was known of previous cycling activity. The first heifer was observed in heat 28 hours after the gonadotrophin injection, 15 other heifers coming in heat in the next 8 hours. Darkness and inability to observe the heifers did not permit determination of the total number coming in heat. Only one heifer was in heat the following morning at which time the whole group was inseminated with good quality Angus semen and turned out to pasture with Hereford bulls. The cooperator, who observes his herd daily, noted that in the following month about 25% of the heifers had come back in heat. The data on

[3] Thirty-three heifers about 5 months pregnant received the same treatment. Four of this group came in heat one day after the gonadotrophin injection. The treatment did not interfere with the normal course of pregnancy and all of the pregnant animals carried to term.

the number of pregnancies resulting from this treatment are not yet available.

A fourth trial was conducted in a group of 20 "feeder heifers" 14–16 months of age and weighing about 550 lb. each (table 6). They were checked at least twice daily with vasectomized bulls and only 10 of the

TABLE 6. THE EFFECTS OF PROGESTERONE AND GONADOTROPHIN ON MATURE AND IMMATURE HEIFERS

Heifer No.	Day of cycle progesterone inject.[a]	Days from initial inject. to estrus	Days from day–1 to estrus
	Mature heifers		
145	3	16	18
81	4	16	18
33	5	18	22[b]
127	7	17	23
6	8	18	25
66	8	17	24
129	14	16	29
140	15	16	30
143	18	16	32
20	25	18	42
	Immature heifers		
135	—	15	—
141	—	16	—
64	—	17	—[b]
67	—	15	—[b]
144	—	18	—
5 heifers	—	No estrus	—

[a] Followed 15 days later with 750 I.U. Equine Gonadotrophin.
[b] Conceived following insemination at the controlled estrus.

20 heifers were found to be sexually mature as indicated by their showing estrus and in the two month pre-treatment period. All 20 heifers were treated on the same day with 560 mg. of progesterone suspension and 15 days later with 750 I.U. of equine gonadotrophin. The initial injection of progesterone was administered at all stages of the estrous cycle (Column 2, table 6). All of the ten heifers showing pre-treatment estrous activity were brought into heat within a 3 day range, 16–18 days after the progesterone injection. Five of the immature heifers were brought into heat 15–18 days post-progesterone injection. Two heifers (135 and 67) came in heat 15 days post-progesterone injection, before the gonadotrophin was administered, and were injected with gonadotrophin while in heat. The 15 heifers showing estrus 15–18

days post-progesterone injection were inseminated with good quality Angus semen. Three heifers were found to be pregnant 50–60 days post-insemination, heifer 33 carrying two normal fetuses, crown rump length 4 cm., and heifers 64 and 67 each carrying one normal fetus, crown rump length 4–5 cm.

The use of progesterone followed by a single injection of equine gonadotrophin resulted in a greater number of the treated heifers coming in estrus than with progesterone alone, and all of the heifers examined following this controlled estrus had ovulated. It has been possible by varying the gonadotrophin dosage to induce multiple or single ovulations and pregnancy, although the conception rate following the controlled estrus is low (17%). The difficulty encountered in this treatment was timing of the gonadotrophin injection to be given during the synchronized follicular growth stage, after the exogenous progesterone inhibition had worn off. The fertility of ova shed during the luteal phase of the cycle has been shown to be low (Casida, 1940) and presumably this would be true if ovulation were induced in the face of high exogenous progesterone, a possible factor to be considered in the low fertility encountered in these studies. On the other hand, superovulating doses of gonadotrophin may result in ova descending the tract at an abnormal rate resulting in low fertility (Dowling, 1950). Further studies are needed to determine whether this low rate of fertility can be corrected, since the control of estrus and ovulation has been successful by the methods described.

Summary

Studies involving 179 beef heifers were conducted to determine if estrus and ovulation could be controlled by limited hormonal treatment.

A single injection of from 540–1120 mg. of crystalline progesterone in starch emulsion was capable of preventing estrus and ovulation in all of the treated heifers, regardless of the stage of the estrous cycle when treatment was given. Estrus occurred 15–19 days after the progesterone injection in 89% of the heifers receiving 540–560 mg. of progesterone, and 15–23 days after the progesterone injection in heifers receiving 700–1120 mg. of progesterone; ovulation occurred in 95% of the heifers examined following this controlled estrus. Normal pregnancy resulted in the two heifers inseminated at the controlled estrus.

When the initial injection of 560 mg. of progesterone was followed 15 days later by a single injection of equine gonadotrophin in normally cycling heifers, 90% came in heat 16–19 days after the progesterone

injection or 1–4 days following the gonadotrophin injection. A single ovulation or multiple ovulations were demonstrated to have occurred in all heifers examined at the post-injection estrus. The conception rate (17%) was very low with this method of treatment.

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THE EFFECT OF BIRTH WEIGHT, AGE OF DAM AND TIME OF BIRTH ON SUCKLING GAINS OF BEEF CALVES [1]

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RATE of gain made from birth to weaning has been recognized as one of the important traits in beef production for many years. Suckling gains have been used in several studies as a criterion of cow productivity. Many studies have indicated that suckling gains or weaning weight adjusted for age should be included in a selection index for beef cattle improvement. The present study is an attempt to evaluate the importance of some factors affecting suckling gains.

Materials and Methods

The purebred Hereford and Aberdeen Angus bulls and heifers studied were dropped in the springs of 1953 and 1954. Birth weights were obtained on all calves and weekly weights were obtained until they were weaned at approximately 450 lb. Rate of gain during the suckling period was calculated by subtracting the birth weight from weaning weight and dividing by the number of days from birth to weaning.

Time of birth was arbitrarily divided into 20-day periods beginning with March 1, since it was not known whether time of birth had a linear effect on suckling gains. The breeding season was for 90 days and the first calving date was about March 15. The ages of the dams studied were grouped as 2,3,4,5–6–7, and 8 years or over. Previous investigations have shown this arrangement to be satisfactory.

The data were analyzed by the method of least squares using a regression model as described by Anderson and Bancroft (1952).

Results and Discussion

The means for birth weights and suckling gains by lines and sexes are presented in table 1.

Large apparent sex differences in rate of gain during the suckling period were found (table 1). However, when appropriate corrections for differences in birth weights are considered, this sex difference was not

[1] This study was conducted in cooperation with the A.R.S., U.S.D.A., and State Department Stations under Western Regional Project W-1 on Beef Cattle Breeding Research. Approved for publication as technical paper 937, Department of Animal Husbandry, Corvallis, Oregon.

significant (table 3). It is not likely that age of dam and time of birth would differentially affect the gains made by calves of the respective sexes. The data would indicate that the difference in suckling gains exhibited by the two sexes is largely due to a difference in birth weight. The males were heavier at birth and carried this advantage through the suckling period. Also, the larger calves at birth gained more rapidly during the suckling period. The regression coefficient of rate of gain during

TABLE 1. AVERAGES FOR BIRTH WEIGHTS AND SUCKLING GAINS OF THE TEST CALVES

Line and sex	Number	Birth weight	Daily gains	
				Adjusted[a]
		lb.	lb.	lb.
Lionheart				
Males	8	73.5	1.86	1.76
Females	13	73.2	1.63	1.58
Prince				
Males	18	75.1	1.65	1.50
Females	10	68.2	1.81	1.54
David				
Males	13	66.0	1.64	1.58
Females	8	64.5	1.43	1.45
Angus				
Males	16	63.1	1.94	1.90
Females	17	57.4	1.90	1.88

[a] Adjusted for age of dam, period of birth and birth weight.

the suckling period on birth weight was 0.0115. This indicates that for each change of 10 lb. in birth weight there was associated a difference in rate of gain of 0.115 lb. per day. Thus, it appears that bulls and heifers of the same birth weight gained at approximately the same rate during the suckling period. The apparent faster gains of male calves from birth to weaning is in agreement with previous investigations (Black and Knapp, 1936; Knapp and Black, 1941; Koch, 1951; Koger and Knox, 1945).

There appeared to be a large difference between calves of 2-year-old dams and those of older cows (table 2). However, the effect of age of dam on rate of gain during the suckling period only approached significance. This is in contrast with most studies (Knapp *et al.*, 1942; Knox and Koger, 1945; Rollins and Guilbert, 1954; Burgess *et al.*, 1954). Time of birth in the present study could have accounted for some of the effect of age of dam, since most 2-year-old dams calved

late in the season due to registration restrictions or the lateness in which they came into first heat. However, selection has been applied for increased suckling gains. It would appear that sufficient progress had been made in improving this trait to the extent that suckling gains of calves from young cows more nearly approached those of calves from the mature cows, which were unselected. The older cows were the original

TABLE 2. ESTIMATE OF EFFECTS

Item	Estimate of effect	
Mean daily gain 1.63	lb. per day	
Lines		
Lionheart	—.012	
Prince	—.121	
David	—.111	
Angus	.245	
Age		
2's	—.182	
3's	—.009	
4's	—.018	
5 5–6–7's	.040	Deviations from the mean
8 and above	.169	
Period of birth		
Period 1	.041	
Period 2	.201	
Period 3	.055	
Period 4	—.054	
Period 5	—.068	
Period 6	—.175	
Regression of gains on birth weight [a] (per lb.) 0.0115.		

[a] Mean birth weight, 67.3.

animals on which no records were available, whereas the younger cows were all selected on the basis of growth rates. Under the conditions in which this study was conducted pastures were somewhat less productive late in the season. It seemed that heifers which calved early in the season tended to raise a calf which gained well. However, the calves from 2-year-old dams calving later had the lowest gains (table 2).

Time of birth is an obvious factor to consider in an area where the productivity of the pastures varies throughout the season. This was particularly true in this study because all of the yearling heifers which came into heat were bred during the 90-day breeding period. In conducting a program of this type the young heifers usually calve late.

This study would indicate that time of birth has an equal or greater effect on rate of suckling gains of the calves than age of dam when the younger dams are selected for this trait and compared with older cows in which little selection has been practiced. The early calves gained at a considerably higher rate than did the calves born late (table 2). With the exception of period one the calves born in the first part of the season gained 0.20 lb. more daily than the mean, or 0.38 lb. more daily than those born in the last part of the season, even though the breeding season was restricted to 90 days.

TABLE 3. ANALYSIS OF VARIANCE

Source of variation	d.f.	M.S.
Lines	3	.4901*
Sex	1	.0028
Age of dam	4	.1577
Time of birth	5	.1966*
Years	1	.0002
Birth weight	1	.6191*
Error	87	.0687

* Significant (P>.05).

The line difference in suckling rate of gain is due largely to the greater gains of the Angus calves. The difference in suckling gains among the three Hereford lines is negligible (table 2). There was no difference between years in suckling gains. General observations revealed that calves were born over approximately the period of time (90 days) for the two years.

Summary

One hundred three purebred Hereford and Aberdeen Angus calves were used in this study. The data included two years—1953 and 1954. Time of birth was broken down, arbitrarily, into 20-day periods beginning with March 1. The other variables were used in the usual manner.

The data were analyzed using the method of least squares. Lines, time of birth, and birth weight all affected rate of gain during the suckling period. There was a difference of 0.115 lb. per day in rate of suckling gains associated with each difference of 10 lb. in birth weight. There was little or no effect of age of dam even though large differences appeared to exist between two-year old and older cows.

There was apparently no direct effect of sex on rate of suckling gain. This would indicate that on removal of the birth-weight effect, the females approached the males in suckling gains.

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FACTORS AFFECTING WEANING WEIGHTS OF CROSSBRED SPRING LAMBS [1]

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THE production of spring lambs is a special type of enterprise which for success demands breeding for the right kind of animal and providing succulent, highly nutritive, cheap feed. The object is to provide, in lambs, fast rate of growth from birth to slaughter and simultaneously to produce a sufficient amount of fat to suit the public's demand. An understanding of the factors which influence the development and growth of sheep will suggest changes in the breeding and management systems to minimize influences which reduce production efficiency. The purpose of this study was to compare the commercial value of various breed crosses of sheep in a specific environment, the Willamette Valley of Oregon, and to measure the extent to which heredity and environment influence weights of lambs at weaning. The endpoint of lamb production is the carcass; however, for the lamb producer the endpoint is the time when the lamb goes to market. Weaning weight and consequently, sale weight in farm flocks play a large part in the determination of income from lamb production.

Review of Literature

Rate of growth in sheep is controlled genetically according to Bonsma (1939); however, its expression is subject to environmental modification.

Nelson *et al.* (1950) found that under Willamette Valley conditions, Hampshire rams sired crossbred lambs which were fat and heavy at weaning, Border Leicester rams sired lambs which were large but only moderately fat, Cheviot rams sired lambs which excelled in finish but were of light weight, while those sired by Romneys were lacking in finish and weight.

Miller (1935) asserted that Suffolk rams sired crossbred lambs which were heavier at weaning than those sired by Hampshire, Shropshire, Romney, Rambouillet or Southdown. The excellence of Southdown rams as sires of quality lambs has been also acknowledged by Sutton, Thomas, and Davenport (1934), Nelson *et al.* (1950), and Hultz, Gorman and Wheeler (1935).

[1] Technical Paper 938. Oregon Agricultural Experiment Station.
[2] Department of Animal Husbandry and Experiment Station Statistical Service.

Bonsma (1939) found that crossbred lambs had a significant advantage in live weight at 12 and 18 weeks. He found no differences in relative growth but noted that the crossbreds maintained the advantage in weight established at birth. Cadmus (1949) found that each pound increase of birth weight above the mean will result in 2.5 to 3.5 lb. increase above the mean weight at 20 weeks depending on the breed. Phillips and Dawson (1937) found that each pound increase in birth weight was associated with 4.3 lb. increased weight at three months. Bonsma (1939) stated that individual selection for high milk production is more important than choice of breed.

Numerous workers have shown that type of birth (twins vs. singles) and rearing have a tremendous effect on growth rates of lambs. Range sheepmen generally run twins in separate bands apart from singles and afford them the better pastures. Price *et al.* (1951) found that type of birth influenced weanling traits more than did any other factor studied. Phillips and Dawson (1937) showed differences due to birth type even when weaning weights were adjusted for birth weights. An advantage in weights of 20, 22, and 29% was found for single lambs compared with twins by Stark (1944), Nelson and Ven Katachalam (1949) and Hammond (1952), respectively.

Differences in maturity and growth rate have been shown to exist between the sexes. Weight differences in favor of ram and wether lambs have been demonstrated by Karam, Chapman and Pope (1949), Hazel and Terrill (1945 and 1946), and Phillips and Dawson (1937).

Materials and Methods

Breeding and Management

The data employed in this study were taken from the files of the Oregon State College Sheep Improvement Program. The study embodies two years' observation of crossing breeds of sheep in an attempt to seek out adaptable breeds and/or breed crosses which have the inherent ability of producing lamb and wool in the commercial hill pasture areas of Western Oregon. It is based on 224 matings and the resulting 280 lambs.

A basic flock of 120 Lincoln $\times$ Rambouillet ewes was divided into four groups, a group to be bred to good rams of the Romney, Border Leicester, Cheviot and Hampshire breeds. The first-cross offspring were 25% Lincoln, 25% Rambouillet and 50% of whichever ram breed (Hampshire, Border Leicester, Cheviot or Romney) was their sire. The first-cross ewes were then backcrossed to rams of their respective sire

breed to derive the second-cross animals. The breeding of the second-cross lambs was, therefore, 75% of the breed of the sire, 12.5% Lincoln and 12.5% Rambouillet. The period from 1946 to 1950 was devoted to developing these crosses.

The first- and second-cross ewes were outcrossed during the fall of 1951 and the fall of 1952 to Suffolk and Southdown rams to determine their relative value for commercial production. Different rams were used in consecutive years to reflect a more accurate picture of the *ram breed* merit. Because of the inability to separate the role of the crosses and of age because of confounding, analyses were conducted within crosses and within years. The age of dam within first and second crosses was the same for ewes bred to Southdown and Suffolk rams.

The ewe flock was managed according to commercial practices recommended for Western Oregon. They were run year long on pasture with supplemental feed being given them only prior to the breeding and lambing seasons. All the ewes were subject to the same management, and the feeding and climatic conditions were considered random or free from bias; thus, the differences among the lambs were due to breed, to individual ewe productivity, to factors such as sex, type of birth, and age, and to unidentified environmental factors. Birth weights were taken to the nearest 0.1 lb. as soon as the lambs were dry and had nursed. The lambs were dropped from February 1 to March 20, and were marketed as they reached top condition and/or heavy market weights. Marketing time was used as the time of weaning although some lambs were obtaining little or no milk from the ewe for some time before they were marketed. They were moved out in three groups at weekly intervals beginning June 1.

The average age of the lambs at weaning was approximately 120 days. Individual lamb weights from previous studies (Bogart, 1955) and from the present (not given here) data indicated that under the existing environmental conditions lamb growth was linear up to 135 days. Hence the individual lamb weight was corrected to 120 days of age by use of the following equation:

$$\text{Corrected weight} = \frac{(\text{Actual weight} - \text{Birth weight})}{\text{Actual age in days}} 120 + \text{Birth Weight}$$

The data in figures 1, 2 and 3 are presented for 91 days only because part of the lambs were marketed at this age. Presentation of material beyond this age would be possible on only part of the better-doing lambs.

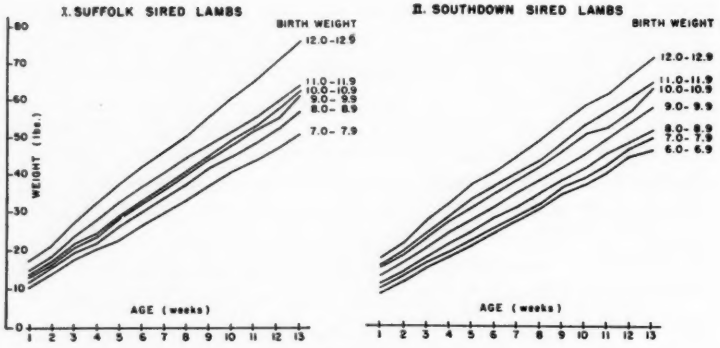

Figure 1. Relation of birth weight to growth of lambs.

Methods of Analysis

The analysis of potential differences in growth rates was conducted on lambs alive at weaning with no regard for mortality which may have occurred within subgroups prior to weaning. Hence the study is one of differences in relative growth of lambs and of the effect of some environmental factors on lamb growth. The least squares method of estimation (Anderson and Bancroft, 1952) was used in the analysis of the data.

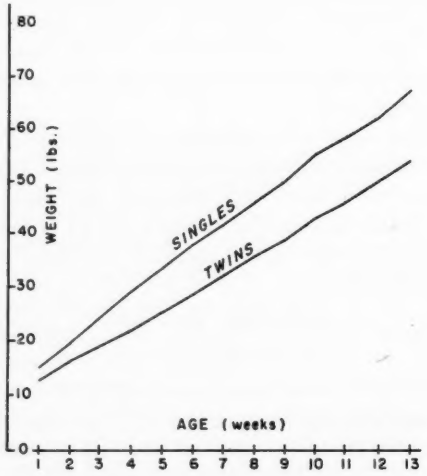

Figure 2. Comparative growth rates of twin and single lambs.

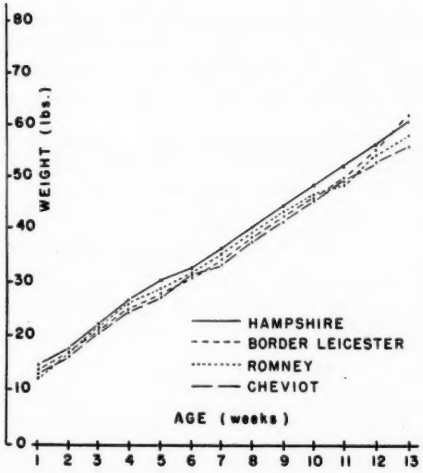

Figure 3. Comparative growth rates of lambs from the four breed crosses of ewes.

Each observation on weaning weight was assumed to be the sum of the influences or effects of other variables as follows:

$$Y_{ijkm}=M+R_i+E_j+(RE)_{ij}+B_k+S_m+(BS)_{km}+e_{ijkm}$$

where

Y_{ijkm}=corrected weaning weight of the lamb

M=a constant for all lambs, the mean

R_i=a constant for the *i*th ram breed

E_j=a constant for the *j*th ewe breed

$(RE)_{ij}$=a constant for the *i*th ram breed with the *j*th ewe breed, the interaction effect between the *i*th ram breed and the *j*th ewe breed

B_k=a constant for the *k*th birth type, single or twin

S_m=a constant for the *m*th sex, wether or ewe

$(BS)_{km}$=a constant for the *k*th birth type with the *m*th sex, the interaction effect between the *k*th birth type and the *m*th sex

e_{ijkm}=error or failure of the above constants to estimate the corrected weaning weight of the lamb.

This mathematical model, or equation used to represent the relationship among the variables, is not an ideal one but should give an approximation of the actual conditions.

The *mean effect M* in the mathematical model includes the funda-

mental likeness of the observations, due to the fact that all animals were of the same species and were grown in the same general environment. The *breed effects* R_i and E_j are perhaps due to differences in metabolic and physiological patterns imparted to the offspring and, hence, to

TABLE 1. NUMBERS OF LAMBS WEANED, ASSEMBLED ACCORDING TO YEAR, BREED AND TOP-CROSS OF EWE, BREED OF SIRE, SEX AND TYPE OF BIRTH

	Suffolk sired	Southdown sired	Wethers	Ewes	Twins	Singles
1952						
First cross ewes						
Hampsire	10	5	7	8	6	9
B. Leicester	11	6	8	9	10	7
Cheviot	10	7	9	8	8	9
Romney	10	7	6	11	10	7
Second cross ewes						
Hampshire	13	6	9	10	14	5
B. Leicester	10	3	4	9	6	7
Cheviot	10	4	5	9	4	10
Romney	9	2	4	7	2	9
1953						
First cross ewes						
Hampshire	12	12	11	13	17	7
B. Leicester	12	12	13	11	17	7
Cheviot	11	11	10	12	12	10
Romney	8	9	9	8	9	8
Second cross ewes						
Hampshire	10	9	5	14	10	9
B. Leicester	10	8	11	7	10	8
Cheviot	9	10	9	10	6	13
Romney	8	6	10	4	2	12

differences in rates of maturity. Type of birth B_k affects lamb growth perhaps through limitation of intrauterine food supply per lamb and through limitation of milk supply so vital to growth after birth. Lambs were classified as *wethers* or *ewes* S_m to measure sex effects in this study. The *effect peculiar to the individual lamb* (error) includes such effects as individual ewe productivity and accidents or other environmental incidents not measurable for analysis.

In addition to the model given above, a second model which incorporates the effect of birth weight was also used. The model is the same with the addition of the term bW where b is the regression coefficient of weaning weight on birth weight and W is the birth weight. The term

bW gives the effect on gains over 120 days to be expected from a given birth weight.

The number of lambs weaned are listed in table 1 according to their various classifications.

Results and Discussion

Estimates of the effects in the mathematical model are presented in table 2 ignoring birth weight, and in table 3 with birth weight included.

The difference in weights between the Suffolk and Southdown-sired

TABLE 2. ESTIMATES OF THE EFFECTS OF CERTAIN VARIABLES ON WEANING WEIGHT OF LAMBS

		Value			
		1952		1953	
Variable	Symbol	First cross	Second cross	First cross	Second cross
Mean	M	83.18	78.12	75.22	70.37
Suffolk ram	R_1	3.03	−.94	1.34	6.26 *
Southdown ram	R_2	−3.03	.94	−1.34	−6.26
Hampshire ewe	E_1	3.66	.54	4.96	6.33
B. Leicester ewe	E_2	−1.75	1.39	−2.20 *	7.24 *
Cheviot ewe	E_3	1.09	−1.49	−1.18	−6.50
Romney ewe	E_4	−3.00	−.44	−1.56	−7.07
Suff. & Hamp.	$(RE)_{11}$	−.89	3.80	−.98	−.92
Suff. & B.L.	$(RE)_{12}$	.99	.72	2.36	−4.40
Suff. & Chev.	$(RE)_{13}$	.64	−.40	.56	3.48
Suff. & Rom.	$(RE)_{14}$	−.74	−4.12	−1.94	1.84 *
South. & Hamp.	$(RE)_{21}$	.89	−3.80	.98	.92
South. & B.L.	$(RE)_{22}$	−.99	−.72	−2.36	4.40
South. & Chev.	$(RE)_{23}$	−.64	.40	−.56	−3.48
South. & Rom.	$(RE)_{24}$	.74	4.12	1.94	−1.84
Single	B_1	8.94 *	7.85 *	8.14 *	8.92 *
Twin	B_2	−8.94	−7.85	−8.14	−8.92
Wether	S_1	−2.06	.70	3.00 *	2.46
Ewe	S_2	2.06	−.70	−3.00	−2.46
Single & wether	$(BS)_{11}$	2.34	.84	−.34	.76
Single & ewe	$(BS)_{12}$	−2.34	−.84	.34	−.76
Twin & wether	$(BS)_{21}$	−2.34	−.84	.34	−.76
Twin & ewe	$(BS)_{22}$	2.34	.84	−.34	.76
Error variance	s^2	6642	4733	4391	3807
Sample size	n	66	57	87	70
Coefficient of determination	R^2	.61**	.45**	.64**	.70**

* Significant differences among the bracketed set at $P \neq .05$.
** Significantly different from zero at $P \neq .05$.

lambs was significant in the 1953 second cross where Suffolk-sired lambs averaged 12 lb. more at 120 days of age than Southdown-sired lambs, when birth weight was ignored. The Suffolk-sired lambs were significantly heavier at 120 days in both second-cross groups when adjustment was made for birth weight. The overall tendency favored the Suffolk rams as sires of heavy lambs.

TABLE 3. ESTIMATES OF THE EFFECTS OF CERTAIN VARIABLES, INCLUDING BIRTH WEIGHT, ON WEANING WEIGHT OF LAMBS

		Value			
		1952		1953	
Variable	Symbol	First cross	Second cross	First cross	Second cross
Mean[a]	M	50.38	20.46	50.35	41.13
Suffolk ram	R_1	1.75	6.80 *	−.58	5.66 *
Southdown ram	R_2	−1.75	−6.80	.58	−5.66
Hampshire ewe	E_1	.81	7.00	1.62	6.21
B. Leicester ewe	E_2	−3.77	−4.13 *	−2.11	3.27 *
Cheviot ewe	E_3	.58	2.02	.98	−2.87
Romney ewe	E_4	2.38	−4.89	−.49	−6.61
Suff. & Hamp.	$(RE)_{11}$	.93	−1.33	3.67	−.77
Suff. & B.L.	$(RE)_{12}$	.76	1.51	.73	−3.18
Suff. & Chev.	$(RE)_{13}$	1.66	−1.57	−1.44	1.90
Suff. & Rom.	$(RE)_{14}$	−3.35	1.39	−2.46 *	2.05 *
South. & Hamp.	$(RE)_{21}$	−.93	1.33	−3.67	.77
South. & B.L.	$(RE)_{22}$	−.76	−1.51	−.73	3.18
South. & Chev.	$(RE)_{23}$	−1.66	1.57	1.44	−1.90
South. & Rom.	$(RE)_{24}$	3.35	−1.39	2.46	−2.05
Single	B_1	4.40	.84	5.72 *	5.98 *
Twin	B_2	−4.40	−.84	−5.72	−5.98
Wether	S_1	−3.04	−1.30	1.92	1.18
Ewe	S_2	3.04	1.30	−1.92	−1.18
Single & wether	$(BS)_{11}$	2.13	1.60	.14	.72
Single & ewe	$(BS)_{12}$	−2.13	−1.60	−.14	−.72
Twin & wether	$(BS)_{21}$	−2.13	−1.60	−.14	−.72
Twin & ewe	$(BS)_{22}$	2.13	1.60	.14	.72
Birth weight	b	3.71**	5.96**	2.50**	3.05**
Error variance	s^2	5523	1996	3673	2735
Sample size	n	66	58	87	70
Coefficient of determination	R^2	.68**	.77**	.70**	.78**

* Significant differences among the bracketed set at $P \neq .05$.
** Significantly different from zero at $P \neq .05$.
[a] Estimated mean at birth weight equal to zero.

The Hampshire-cross ewes generally produced the fastest growing lambs of the breeds compared (table 2 and figure 3). The Hampshire-crosses particularly produced faster growing lambs than did the Cheviot and Romney-cross ewes. There was no significant difference in the growth rates of Cheviot and Romney-cross lambs in any case. The rank of the ewe breeds is in accordance with the report of Nelson *et al.* (1950) on the comparison of rams of those breeds as sires of spring lambs. It is assumed from the work of Bonsma (1939) that the more rapid growth and the greater finish of lambs produced by Hampshire ewes may indicate that they produce more milk.

There was an interaction of breed of ram and breed of ewe. When Border Leicester ewes were bred to Southdown rams, the lambs that were produced grew more rapidly and became fatter than when these ewes were bred to Suffolk rams. Also, when Cheviot ewes were bred to Suffolk rams, the lambs grew more rapidly than lambs by these ewes sired by Southdown rams. It appears that more heterosis resulted when wider crosses were made.

The coefficients of determination R^2 indicate that from 45 to 78% of the variation in weaning weight is accounted for by variations in the factors studied.

This method of evaluation points out the merits of the average lamb of a breed but fails to measure actual breed merit since no account is made for lambing percentage, mortality, nor production per hundred weight of ewe. The lambing percentages were 134, 127, 124, and 115 for Hampshire, Cheviot, Border Leicester and Romney-cross ewes, respectively. Mortality was 6.4, 5.7, 4.8 and 14.8% for Hampshire, Cheviot, Border Leicester and Romney-cross ewes, in that order. It is suggested that additional differences do exist in the economic value of these breed crosses of ewe when lambing percentage, mortality, and ewe weight are considered, which do not show when the measurement is made solely on the average live lamb (Bogart, 1956). Winters *et al.* (1946) and Miller and Dailey (1951) have also shown the importance of mortality, lambing percentage, and ewe weight in evaluation of production per ewe.

Birth weight was the most influential of all the variables affecting weaning weight which were studied (table 3). The regression of weaning weight on birth weight was, in all four analyses, high and significant. The range of increase in weaning weight varied from $2.50 \pm .65$ to $5.96 \pm .76$ lb. for each pound increase in birth weight. The lambs were grouped according to birth weight, ignoring breed of ewe, sex, or type of birth for plotting figure 1. The effect of birth weight on subsequent

weights is quite clearly illustrated. In no case was there an overlap in the weight increase of lambs of a given birth weight and those of another. The advantage enjoyed by the lambs which were larger at weaning was in part established at birth. Other workers, Phillips and Dawson (1937), Hazel and Terrill (1945, 1946), Nelson *et al.* (1949), Price *et al.* (1951), and Hammond (1952), have shown that single lambs are larger at weaning than twins. The present paper shows that this advantage of single over twin lambs is partly due to the birth weight advantage possessed by single lambs. In the 1953 second-cross where no adjustment for birth weight is made, singles were 18 lb. heavier than twins at weaning. If adjustment is made for birth weight, singles still have a 12 lb. advantage in weaning weight, (table 2 and figure 2). The importance of birth weight on subsequent weights suggests that in order to get large lambs at weaning, one should consider the choice of breed in addition to the ability of the individual within a breed to produce lambs which are large (within limits) at birth.

Lambs born as singles weighed, on the average, 17 lb. more at weaning than did those born as twins. Birth type imparts the greatest barrier on growth of any of the environmental factors studied. The comparative growth rates of lambs born as singles and as twins are illustrated in figure 2. The difference between singles and twins was significant in all cases when birth weight was ignored. Single lambs were heavier than twins in 1953 even when adjustments were made for differences in birth weights. When adjustments for birth weights were made on the 1952 data, the difference between singles and twins was eliminated. Several workers, Karam *et al.* (1949), Hazel and Terrill (1945 and 1946), and Philips and Dawson (1937), have shown that male lambs reach heavier weaning weights than female lambs. The present study indicates that a part of the advantage of male lambs in weaning weight results from the larger birth weights of the male. Thus, heavier lambs at birth indicate rapid growth rates which are expressed prenatally and which result in heavier weaning weights.

Summary

Suffolk rams tended to sire lambs which were heavier at weaning than did Southdown rams, although the differences were not significant.

Hampshire-cross ewes produced the fastest growing lambs of the breeds compared. Hampshire-cross lambs were significantly heavier than Cheviot and Romney-cross lambs. There were no significant differences in the weights of Cheviot and Romney-cross lambs.

This study is concerned with weaning weights on a lamb rather than ewe basis. Lambing percentages were 134, 127, 124, and 115 for Hampshire, Cheviot, Border Leicester, and Romney-cross ewes, respectively, and lamb mortality was 6.4, 5.7, 4.8, and 14.8%, in the same order.

Birth weight was one of the most influential of the variables which was studied. The differences among breeds are partly due to differences in birth weights. The regression of weaning weight on birth weight ranges from $2.50 \pm .65$ to $5.96 \pm .76$ lb. increase in weaning weight for each pound increase in birth weight. In the production of heavy spring lambs, the ability of individuals within a breed to produce lambs which are large at birth should be considered as well as a choice of a breed.

Birth type imparted the greatest effect on lamb growth of any of the environmental factors studied. Single lambs weighed, on the average, 17 lb. more at weaning than did twin lambs. A large portion of the difference in weights of singles and twins is established at birth; however, in years of good feed supply, the relative growth rates may be similar.

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THE EFFECTS OF ORAL ESTROGENS AND ANDROGENS SINGLY AND IN COMBINATION ON YEARLING STEERS [1]

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DATA from various experiment stations have shown a growth-stimulatory effect of female hormone-like materials when they are implanted subcutaneously (Andrews *et al.*, 1954; Dinusson *et al.*, 1950) or when they are fed (Burroughs *et al.*, 1954, 1955; Perry *et al.*, 1955) to growing and fattening cattle in drylot. Research data from the implantation (Andrews *et al.*, 1954; Dinusson *et al.*, 1950) and intramuscular injection of male hormones have been published (Burris *et al.*, 1953) but little or no data concerning the effect of feeding male hormone-like materials are available.

The experiment reported in this paper was designed to study the effect of feeding the male hormone—methyl testosterone—alone or in combination with diethylstilbestrol to yearling steers fed a fattening ration in drylot.

Experimental

Thirty-six yearling Hereford steers averaging 750 lb. liveweight were divided into four lots of nine each and fed a fattening ration of corn silage, Supplement A and minerals in drylot. (Formula for Purdue Supplement A, 1000 lb. mix: Soybean meal, 650 lb.; dehydrated alfalfa meal, 140 lb.; molasses, 140 lb.; bonemeal, 52 lb.; salt with cobalt, 17.0 lb.; vitamin A and D concentrate, 0.5 lb.—contains 4,540,000 U.S.P. units A and 567,500 U.S.P. units D per lb.). Lot I served as a negative control and Lot II received 10 mg. of diethylstilbestrol per animal daily in addition to a full-feed of silage and 3.5 lb. of Supplement A per day. Lot III was fed a combination of 5 mg. of diethylstilbestrol and 50 mg. of methyl testosterone, and Lot IV was fed 175 mg. of methyl testosterone per animal daily in addition to the silage and Supplement A.

The trial extended for 179 days. However, the type of ration being

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fed was changed at the end of 98 days because the supply of corn silage had been exhausted. For the remaining 81 days of the trial, the ration consisted of ground ear corn, ground corn cobs, Supplement A and minerals. The respective hormone treatments were continued throughout the entire 179 days.

All the hormones were dissolved in 500 ml. of corn oil, and this solution was pre-mixed with 10 lb. of soybean oil meal. The hormone premix (weighing 11 lb. because of the addition of the corn oil) was added to 1 ton of Supplement A in an upright twin spiral mixer.

Since the steers were fed 3.5 lb. of Supplement A per day, the following amounts of hormones were added per ton of supplement to allow for the daily hormone intake: Lot I, No hormone; Lot II, 5.714 gm. diethylstilbestrol per ton Supplement A; Lot III, 2.857 gm. diethylstilbestrol and 28.571 gm. methyl testosterone per ton Supplement A; Lot IV, 100 gm. methyl testosterone per ton Supplement A.

At market time, data on dressing percent, shrink and federal carcass grades were obtained. A sample from the twelfth rib was secured from each animal for chemical analysis.

Results

Growth Rate

Steers fed either stilbestrol alone or in combination with the male hormone, methyl testosterone, grew approximately 12% more rapidly than the steers in the lot receiving no hormone. Steers fed only the male hormone gained only slightly faster than steers receiving no hormone. The difference in gain between either the stilbestrol-fed lot (Lot II) or the lot fed both stilbestrol and testosterone (Lot III) was not statistically significant.

Since the feeding regimen had to be changed near the middle of the trial due to depletion of the supply of silage, growth data are presented for the first 98 days, for the last 81 days and for the combination of the two, or 179 days. The increase in growth rate in favor of the steers fed stilbestrol was acquired during the first 98 days of the trial. This early growth response with little or no additional stimulation in the later stages of the trial is in agreement with a previous trial at this station (Perry *et al.*, 1955).

Feed Efficiency

Since all four lots of steers ate approximately the same amount of feed per day, there was an advantage in feed efficiency in favor of

the steers receiving either diethylstilbestrol alone or in combination with testosterone. Stilbestrol-fed steers were 18% more efficient the first 98 days and 5% less efficient the latter 81 days than the control; steers fed the combination of male and female hormones were 8% and 14% more efficient than the controls for the two respective periods.

Marketing and Slaughter Data

Although shrink in transit to market (65 miles) was slightly less for diethylstilbestrol-fed steers than for the control steers (2.0% vs. 2.3%), diethylstilbestrol-fed steers failed by 1.3% to dress as high ($P<0.05$) as the steers fed no hormone (58.7% for stilbestrol-fed steers and 60.0%

TABLE 1. MALE AND FEMALE HORMONE-LIKE MATERIALS ALONE OR IN COMBINATION FOR YEARLING STEERS

Items	Lot I No hormone	Lot II 10 mg. stilbestrol	Lot III 5 mg. stilb. 50 mg. testo.	Lot IV 175 mg. testo.
Number of animals	9	9	9	9
	Growth rate			
Initial wt.	754	751	753	752
Wt. at 98 days	1019	1074	1041	1032
Daily gain, 1st 98 days	2.71	3.30	2.94	2.86
Wt. at 179 days	1175	1221	1222	1188
Daily gain, last 81 days	1.92	1.81	2.23	1.93
Daily gain for 179 days	2.35	2.63	2.62	2.44
	Feed consumption, lb.			
Phase I, 1st 98 days				
Corn silage	52.2	52.3	52.2	52.3
Supplement A	3.5	3.5	3.5	3.5
Phase II, last 81 days				
Gr. corn cobs	8.8	8.8	8.8	8.8
Gr. ear corn	12.5	12.5	12.5	12.5
Supplement A	3.5	3.5	3.5	3.5
	Feed per 100 lb. gain, lb.			
Phase I, 1st 98 days				
Corn silage	1925	1584	1773	1830
Supplement A	129	106	119	122
Phase II, last 81 days				
Gr. corn cobs	457	483	393	456
Gr. ear corn	650	686	559	649
Supplement A	182	192	156	182

for steers fed no hormone, table 2). The control steers fed no hormone showed an approximate 1% advantage over the diethylstilbestrol-fed steers when both shrink-in-transit and dressing percent were considered. Steers which received both female and male hormone dressed 62.1%, and, even with a higher shrink in transit, (3%) showed the best per-

TABLE 2. EFFECT OF MALE AND FEMALE HOMONE-LIKE MATERIALS ON SHRINK, CARCASS QUALITY AND COMPOSITION

Items	Lot I No hormone	Lot II 10 mg. stilbestrol	Lot III 5 mg. stilb. 50 mg. testo.	Lot IV 175 mg. testo.
Final wt., lb.	1175	1222	1222	1188
Market wt., lb.	1148	1198	1183	1149
Transit shrink, %	2.3	2.0	3.0	3.3
Hot carcass wt., lb.	700	714	746	691
Cold carcass wt., lb.	689	704	734	680
Dressing, %	60.0	58.7*	62.1**	59.2
	Carcass grades			
U. S. choice	7	4	2	4
U. S. good	2	4	6	5
U. S. commercial	0	1	1	0
	Chemical analysis of twelfth rib			
Moisture, %	42.5	47.4*	42.5	46.9*
Fat, %	44.8	38.3*	40.8	38.6*
Protein, %	12.3	14.2**	13.7**	14.4**

* Significant at the 5% level.
** Significant at the 1.0% level.

formance when the marketing and slaughtering phases were combined.

Since no completely satisfactory method of analyzing differences in carcass grades has been developed, it is not possible to determine whether the lower grades of the carcasses of stilbestrol-fed steers and of the carcasses of steers fed a combination of stilbestrol and testosterone are statistically different from the higher grades of the carcass of steers fed no hormones. A similar reduction in carcass grade has been reported previously (Perry *et al.*, 1955).

Chemical Composition of the Meat

The twelfth rib (backbone to sternum) and the accompanying meat were removed from one side of each carcass. The meet was removed from the rib, ground and mixed in a Hobart food chopper. Thus, a separate sample from each steer was provided for chemical analysis

(table 2). The data from the chemical analysis indicated the loin eye and other meat connected to the twelfth rib contained significantly different (P 0.05) amounts of fat, protein and water between treatments under the conditions of this trial. Meat from the animals fed no hormone contained 6.5% more fat (44.8% vs. 38.3%) than meat from the animals fed stilbestrol, 4.9% less water (42.5% vs. 47.4%) and 1.9% less protein (12.3% vs. 14.2%).

Discussion

The beneficial effects of the oral treatment of cattle with diethylstilbestrol on feed efficiency and rate of gain reported here are in general agreement with previous work. These data likewise agree with what has been reported on the effects of stilbestrol on carcass quality, namely, that it either does not improve carcass grade or slightly reduces carcass grade.

Under the conditions of this experiment, the dual treatment with diethylstilbestrol and methyl testosterone could not be considered practical. There was no increase in feed efficiency or rate of gain over the steers treated only with the estrogen. Furthermore, the cost of the androgen greatly increased the cost of treatment.

In laboratory animals, the androgens have well known protein anabolic effects. Burris *et al.* (1953) have been able to demonstrate that the intramuscular injection of testosterone will significantly increase rate and efficiency of gain in cattle. Failure of steers to respond to subcutaneous implantation of androgen pellets (Andrews *et al.*, 1954) can possibly be explained in terms of a greatly reduced amount of hormone used in comparison with the intramuscular treatment. The inefficacy of the methyl testosterone reported in this experiment may be explained on the basis of oral administration and dosage level.

Summary

The feeding of 10 mg. of diethylstilbestrol or a combination of 5 mg. of diethylstilbestrol and 50 mg. of methyl testosterone to fattening yearling steers resulted in a 12% increase in growth rate over a 179-day trial. The increase in growth rate was not evenly distributed over the entire trial but in the case of stilbestrol-fed steers occurred during the first 98 days of the trial.

All lots of steers consumed approximately the same amount of feed per day. The improvement in feed efficiency of the diethylstilbestrol or

diethylstilbestrol-methyl testosterone steers was of approximately the same pattern as the improvement in growth rate. Stilbestrol-fed steers required 18% less feed per unit of gain during the first 98 days of the trial and 5% more feed per unit of gain during the last 81 days than the control lot which received no hormone. Steers receiving the combination of male and female hormone-like substances required 8% less feed and 14% less feed per unit of gain during the two respective periods of the trial than the control animals.

Steers fed no hormone dressed significantly higher than steers fed diethylstilbestrol (P 0.05), whereas steers fed a combination of stilbestrol and testosterone dressed significantly higher than the steers fed stilbestrol (P 0.05) or steers fed with either testosterone alone or no hormone (P 0.05).

The carcasses from the hormone-fed steers were slightly inferior, according to Federal Grading Standards, to carcasses from steers which had not received hormones.

Twelfth rib samples from carcasses of steers which had not been fed hormone contained significantly more fat and less moisture and protein than those from steers which had been fed either diethylstilbestrol or methyl testosterone.

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THE ORAL ADMINISTRATION OF DIETHYLSTILBESTROL, DIENESTROL, AND HEXESTROL FOR FATTENING CALVES [1, 2]

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DURING the past decade it has been shown that the subcutaneous implantation of diethylstilbestrol or dienestrol pellets will increase rate of gain and efficiency of feed utilization in beef cattle of various weights and under different systems of management (Dinusson *et al.*, 1950; Andrews *et al.*, 1954; Clegg *et al.*, 1954) and that the oral administration of diethylstilbestrol has similar effects on growth and feed utilization (Burroughs *et al.*, 1954; Beeson *et al.*, 1956). Perry *et al.* (1955) showed that in two-year-old steers diethylstilbestrol, dienestrol and hexestrol were of equal effectiveness when fed at levels of 10 mg. per steer per day and that in yearling steers 10 mg. of diethylstilbestrol or 5 mg. of diethylstilbestrol plus 50 mg. of methyl testosterone orally per steer per day were of equal effectiveness during a 179-day feeding period.

The present experiment was designed to compare the oral effectiveness of diethylstilbestrol, dienestrol and hexestrol in feeder calves of both sexes.

Experimental

Thirty-five choice Shorthorn calves averaging about 450 lb. liveweight were divided into four groups of eight or nine calves each. They were full-fed in drylot a ration of shelled corn, Purdue Supplement A and corn silage. Purdue Supplement A is composed of: Soybean meal, 650 lb.; dehydrated alfalfa meal, 140 lb.; molasses, 140 lb.; bone meal, 52 lb.; salt plus cobalt, 17 lb.; and vitamin A and D concentrate, 0.5 lb. (4,540,000 U.S.P. units A and 567,500 U.S.P. units D per lb.). During the last 18 days of the 179-day feeding period, corn silage was unavailable and ground corn cobs were fed as roughage. One group of calves received no hormonal supplement; a second group received 10 mg. of diethylstilbestrol per day orally; a third group received 10 mg. of dienestrol daily; and a fourth group received 10 mg. of hexestrol per day orally. All hormonal substances were dissolved in 500 ml. of corn

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oil and added to Supplement A at levels of 5 mg. of estrogen per pound of supplement.

At the conclusion of the trial, the animals were shipped by truck to Indianapolis—a distance of 65 miles. Weight losses during transit, hot and cold carcass weights, dressing percentage and official Federal carcass grades were obtained. In addtion, a complete cross section of one side of each carcass was made at the twelfth rib. Each rib section was boned, and the meat and fat ground and analyzed for fat, protein and moisture.

Results and Discussion

As summarized in table 1, all estrogen-treated groups gained significantly more ($P<0.01$) than the control group. The total gain of the diethylstilbestrol-treated cattle was 30% greater than the control and significantly greater than that of either the dienestrol or hexestrol groups ($P<0.05$). In an experiment with two-year-old steers, Perry *et al.* (1955) found diethylstilbestrol and hexestrol to be equally effec-

TABLE 1. THE EFFECT OF FEEDING THREE FEMALE HORMONE-LIKE MATERIALS TO FEEDER CALVES

(Feeding period, 179 days)

Items	Lot I No hormone	Lot II 10 mg. stilbestrol	Lot III 10 mg. dienestrol	Lot IV 10 mg. hexestrol
Number of animals	9	8	9	9
	Growth rate			
Initial wt., lb.	477	466	448	430
Final wt., lb.	832	914	863	835
Total gain, lb. (179 days)	346	448**	415**	405**
Daily gain, lb.	2.10	2.50	2.32	2.27
	Feed consumption, lb.			
Shelled corn	10.6	10.8	10.2	10.0
Supplement A	2.0	2.0	2.0	2.0
Corn silage[a]	14.9	15.0	14.9	14.9
Hay	2.7	3.0	3.1	2.7
	Feed per 100 pounds gain, lb.			
Shelled corn	508	433	441	442
Supplement A	95	80	86	88
Corn silage	653	572	614	590
Hay	127	119	133	121

[a] Ground corn cobs were substituted for silage the last 18 days of the trial, and fed at 4.0 lb. per animal daily.

** Significant at the 1.0% level.

tive. In the present experiment, the average initial weight of the hexestrol group (Lot IV) was 36 lb. less than the diethylstilbestrol group and this may have contributed to the difference in gain.

Since the cattle were group fed, statistical analysis of the data for feed efficiency was not possible. Since it has been consistently shown

TABLE 2. THE EFFECT OF THREE FEMALE HORMONE-LIKE MATERIALS ON SHRINKAGE, CARCASS QUALITY AND COMPOSITION

Items	Lot I No hormone	Lot II 10 mg. stilbestrol	Lot III 10 mg. dienestrol	Lot IV 10 mg. hexestrol
Final wt., lb.	823	914	863	835
Market wt., lb.	804	873	823	813
Transit shrink, %	2.3	4.4**	4.6**	2.7
Hot carcass wt., lb.	506	557	522	510
Cold carcass wt., lb.	500	547	517	503
Dressing percent	62.1	62.7	62.5	61.8
	Carcass grades			
High choice	3	5	0	2
Average choice	4	2	5	1
Low choice	2	0	0	2
High good	0	1	1	2
Average good	0	0	0	1
Low good	0	0	2	1
Commercial	0	0	1	0
	Chemical analysis of meat and fat from twelfth rib			
Moisture, %	39.1	39.9	40.7	41.0
Fat, %	48.9	47.7	46.4	44.1
Protein, %	12.6	12.1	13.4	13.6

** Significant at the 1.0% level.

that estrogen alone or in combination with methyl testosterone significantly improves feed efficiency (Dinusson *et al.*, 1950; Andrews *et al.*, 1954; Clegg *et al.*, 1954; Burroughs *et al.*, 1954; Perry *et al.*, 1955; Beeson *et al.*, 1956), it appears justifiable to conclude that the differences in feed efficiency produced by estrogens and shown in table 1 are true differences.

There was a significant increase in transit shrink in the diethylstilbestrol and dienestrol groups ($P<0.01$). There were no appreciable differences between hot and cold carcass weights or dressing percentages. In a companion experiment with yearling steers, Beeson *et al.* (1956) observed no differences in transit shrink between control and diethylstilbestrol-treated cattle but a greater dressing percent in the controls ($P<0.05$).

As shown in table 2, chemical analyses of the meat and fat separated from a twelfth rib section showed that control calves had slightly less moisture and slightly more fat than the estrogen-treated calves, but the differences were not statistically significant. In a study with yearling steers, the control groups also had less moisture than the group which received 10 mg. of diethylstilbestrol daily and more fat than any of the hormone-treated groups (Beeson *et al.*, 1956); these differences were significant ($P<0.05$).

The limitation of comparing carcass grades when small numbers of animals are involved is again pointed out. It was concluded that in the present study there were no differences in carcass grades, but no hormone-treated group was superior to the control. In the companion study previously referred to (Beeson *et al.*, 1956), there were more choice carcasses and greater fat content at the twelfth rib in yearling steers which received no hormone than in the diethylstilbestrol or methyl testosterone-treated groups.

Summary

The oral administration of diethylstilbestrol, dienestrol or hexestrol at levels of 10 mg. per calf per day significantly increased rate of gain in calves fed in drylot over a 179-day period.

The feed required per unit of gain was reduced by all three estrogens.

The percentages of fat, protein and moisture in entire rib sections at the twelfth rib were rather similar for all treatments; the control group had the most fat and least moisture.

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THE INFLUENCE OF THE ORAL ADMINISTRATION OF DIETHYLSTILBESTROL ON CERTAIN CARCASS CHARACTERISTICS OF BEEF CATTLE [1]

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THE effects of subcutaneous administrations of diethylstilbestrol on the rates of gain, the efficiency of feed utilization and the carcass quality of fattening cattle, lambs and poultry have been summarized in a report of the Committee on Animal Nutrition (1953). More recently a review of this subject appeared in Nutritional Reviews (1955). Diethylstilbestrol implantation experiments have provided evidence that the administration of the drug diethylstilbestrol results in increases in rates of gain in cattle and lambs. In most of the investigations it has been implied that the carcass grades of treated animals have been lower than that of control untreated animals. The most frequently reported explanation for assigning lower grades to the carcasses of treated animals is that the carcasses contain less subcutaneous fat and that there are changes in the pelvis, Clegg and Cole (1954).

Several experiments have been conducted at Iowa State College which indicate that oral administration is effective in increasing rate of gain in fattening cattle. The foregoing is a report of the results of investigations of the influence of orally administered diethylstilbestrol on certain carcass characteristics of the beef animals from 4 of the 5 experiments reported in the paper on gains, by Burroughs *et al.* (1955).

Experimental

A detailed description of the animals which served as subjects for this investigation and of the basal and diethylstilbestrol supplemented rations they were fed, are available in a report by Burroughs *et al.* (1955).

In the four, out of five feeding experiments, for which carcass data were obtained, from one to three levels of diethylstilbestrol were fed in addition to a control ration. Each ration was fed to a lot of eight cattle. Steers were used in experiments 1, 2, and 5 and heifers were

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used in experiment 3. The cattle in each experiment were allotted at random by outcome groups based on initial weight. No carcass data were obtained in feeding experiment 4. In experiment 3, carcass data are available for five heifers from each lot since three from each lot were used for a further investigation. A diseased condition developed among 3 animals in experiment 2 and they were removed before the feeding experiments were completed.

The average daily intake of diethylstilbestrol, the initial and final body weights and data for certain carcass characteristics averaged by lots for the 92 beef animals which served as subjects for four series of experiments are shown in table 1. The basal rations for experiments 1, 2 and 3 may be described at high-corn fattening rations. The animals in experiment 5 received a high roughage ration for 168 days but were fed a high-corn fattening ration during the last 75 days of the experiment. The steers (experiments 1 and 2) and the heifers in experiment 3 graded Good to Choice as feeders when placed on the experimental rations. The average feeder grade of the steers in experiment 5 was Good.

The final weights of the animals at the close of the feeding trials were determined by averaging the individual weights of the animals, allowed access to feed and water, taken on three consecutive days. The animals were then maintained on these rations for an additional time (1–14 days) and then denied feed and water for 12 hours, weighed again, graded and sold. The live grades, expected yields and selling prices for animals in experiments 1, 2, and 5 were established by appraisals which were made by a committee of three, representing two cattle buyers from two packing companies and a livestock commission agency. The cattle were then prepared for shipment to a federally inspected meat firm located in Iowa. In all instances, animals after grading and weighing were permitted access to their assigned rations and to water but were given water only after delivery to the slaughter plant.

The elapsed time between weighing, grading and sale and slaughter varied from less than one day to a maximum of two days.

The carcass yields for animals from experiments 1, 2 and 5 were determined by dividing the hot carcass weight taken immediately after slaughter, by the weight of the animal as determined at the end of a 12 hour off-feed and water period, when the grade and selling price appraisals were made. The carcass yields of cattle from experiment 3 were obtained by taking the hot carcass weight and dividing by the weight of cattle upon arrival at the plant.

TABLE 1. THE EFFECT OF ORALLY ADMINISTERED DIETHYLSTILBESTROL ON CERTAIN CARCASS CHARACTERISTICS OF BEEF ANIMALS: AVERAGES BY LOTS

Exp. No.	Level of stilbest. fed mg.	No. of animals	Body Weight		Av. daily gain[a]	Carcass			Fat depth	Rib eye area	Composition 9–10–11 rib		
			Initial	Final		Hot wt.	Yield	Grade[b]			Fat	Lean	Bone
	1 day		lb.	lb.	lb.	lb.	%		mm.	sq. in.	%	%	%
1[c]	0	8	691.5	929.4	2.23	571.8	61.6	6.5	13.9	10.6	30.0	51.8	18.1
	2.75	8	692.7	959.4	2.46	596.5	62.2	6.4	11.0	11.3	28.4	55.9	15.4
	5.50	8	696.2	983.1	2.64	607.2	61.8	7.0	12.0	11.6	28.8	55.3	15.7
	11.00	8	695.8	1023.8	3.06	635.2	62.0	6.4	15.9	12.4	27.6	55.0	17.1
		s[d]			0.39	25.94	1.17	1.19	4.95	1.17	3.69	3.68	1.76
2	0	8	823.5	1108	2.36	702	61.8	7.0	14.0	12.0	33.5	51.3	15.4
	5	8	822.5	1121	2.57	701	60.9	6.6	19.2	12.5	35.0	50.5	14.1
	10	6	830.8	1128	2.53	709	61.2	6.2	14.0	12.3	32.2	52.0	15.7
	20	7	826.0	1181	2.93	740	61.1	6.6	14.4	12.8	32.1	52.6	15.1
		s			0.42	41.09	1.34	1.03	6.19	1.19	5.13	4.44	1.64
3	0	5	640.2	850	2.06	507.2	59.6	7.0	15.4	11.1	35.2	51.0	14.4
	6	5	639.4	880	2.23	518.8	58.9	6.8	13.0	10.8	30.7	54.6	14.1
	12	5	643.0	892	2.30	525.4	58.8	7.2	15.2	10.9	34.0	49.6	15.7
		s			0.41	35.24	0.79	0.73	2.96	0.86	6.29	5.52	2.04
5	0	8	622.3	1039	1.75	653	61.2	7.0	10.7	12.1	27.4	55.7	17.2
	10	8	620.8	1104	2.04	696	61.4	6.6	11.5	13.1	29.1	54.0	16.9
		s			0.17	29.43	1.11	1.13	2.61	0.64	2.62	3.16	1.56

[a] Average daily gain based on weight before being off feed and water for 12 hours.
[b] Federal grade based upon prime plus=12, prime=11, prime minus=10, choice plus=9, choice=8, choice minus=7, good plus=6, good 5, good minus 4.
[c] Days on feed: 112, 120, 113 and 243 days for experiment Nos. 1, 2, 3, and 5, respectively.
[d] The standard deviations, s, are the square roots of the average within lot mean squares after removing the influence of outcome groups.

Individual carcass grades were determined by federal meat graders after the carcasses had been held in the cooler for 24 hours to 48 hours and quartered.

Tracings of the cross section of the longissimus dorsi muscle at the 12th rib, were made at this time. The 9–10–11 rib sections were removed from the carcasses and cut to a standard length. Subsequently, physical separations of the fat, the lean and the bone tissues were carried out, according to procedures similar to those described by Hopper (1944) and Hankins and Howe (1946). They reported that the physical composition of the 9–10–11 rib cut was an excellent indicator of the fat and lean composition of the beef carcass.

The proportions of separable lean, fat and bone are reported as percent of total 9–10–11 rib cut weight and the longissimus dorsi cross sectional areas are recorded as square inches of surface as determined by measurements made in duplicate with the aid of compensating planimeter. The degree of marbling of the longissimus dorsi muscle, the extent of internal and external finish were carefully observed but no systematic records of observations were kept since it was assumed that the difference in carcass grade would reflect variations in these carcass quality attributes.

The thickness of fat cover over the longissimus dorsi at the 12th rib was determined according to the procedure of Clifton and Shepherd (1953).

Since the length of feeding periods, the basal rations, and the periods of time between appraisals of grade and selling price and slaughter and shipping distances prior to slaughter were different for each experimental group of cattle, comparisons among the "dressing percentages" and carcass data are probably valid only when made between treatments within a single experiment.

A statistical study of the data to estimate the influence of level of orally fed diethylstilbestrol on certain carcass characteristics is limited by the fact that only a single lot of animals was fed each level of diethylstilbestrol in each experiment and by the fact that the levels of diethylstilbestrol, the type and weight of animals, and the basal ration and the length of feeding period varied among experiments. In addition, variation among carcass characteristics may have been increased due to variations in quantity of feed consumed by animals within lots and consequently quantity of diethylstilbestrol consumed by animals within lots may have been variable.

Therefore the mean square among carcass characteristics within lots,

after removing the influence of outcome groups, was used as an estimate of experimental error. Such an estimate in these experiments is unbiased only if the lot effects were negligible and if the carcass characteristics among animals within lots were independent of one another. Direct evidence on whether or not these two conditions are sufficiently met, in general, is not available. Indirect evidence can be inferred by considering the influence of these factors on cattle weight gains.

The lot effect on gain in weight in many cattle feeding experiments is probably small, but there are important exceptions. Competition among animals within lots, especially with limited feeding of concentrates, has been observed frequently. Quantitative estimates of the influence of these two factors on the experimental error in cattle feeding experiments is too limited to draw definite conclusions. The lot effect tends to make the mean square among gains within pens an underestimate of the true experimental error, while the competition effect tends to make this mean square an overestimate.

If variation in gains among animals within lots does not supply an unbiased estimate of experimental error, then the same is probably true for carcass characteristics. This is inferred because most carcass characteristics are correlated with gain. Initially similar cattle, fed the same ration, that gain at different rates for some fixed period of time produce carcasses of varying degrees of finish.

Results

The body weights, the average daily gains, the data for the carcass characteristics are summarized in table 1 by experiments and level of diethylstilbestrol fed. In studying the carcass data, attention is directed to the differences among experiments in average initial body weight, final body weight, and hot dressed weight of carcasses. Attention is also directed to the fact that in each experiment every lot of cattle fed diethylstilbestrol made a larger average daily gain than the control lot of cattle.

The mean differences in carcass yields between animals fed diethylstilbestrol and the control animals were small and were not consistant among experiments. For carcass yield the average was somewhat larger for diethylstilbestrol fed cattle than for controls in experiment 1 and 5 but was smaller in experiments 2 and 3. None of these mean differences came close to being statistically significant ($P<.05$).

Bar charts summarizing the data by rations and experiments for

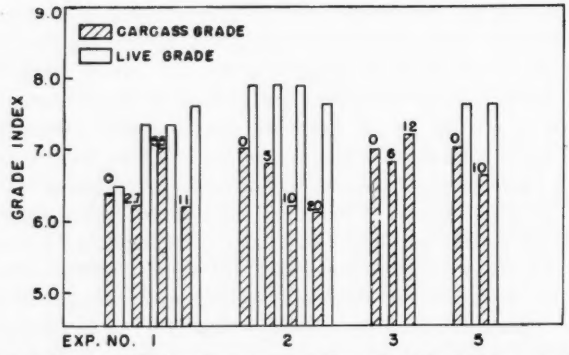

Figure 1. Live animal and carcass grades of cattle fed zero to 20 mg. diethylstilbestrol per head per day. (Grades computed using the following numerical system: Prime plus, 12; Prime, 11; Prime minus, 10; Choice plus, 9; Choice, 8; Choice minus, 7; Good plus, 6; Good, 5 and Good minus, 4.)

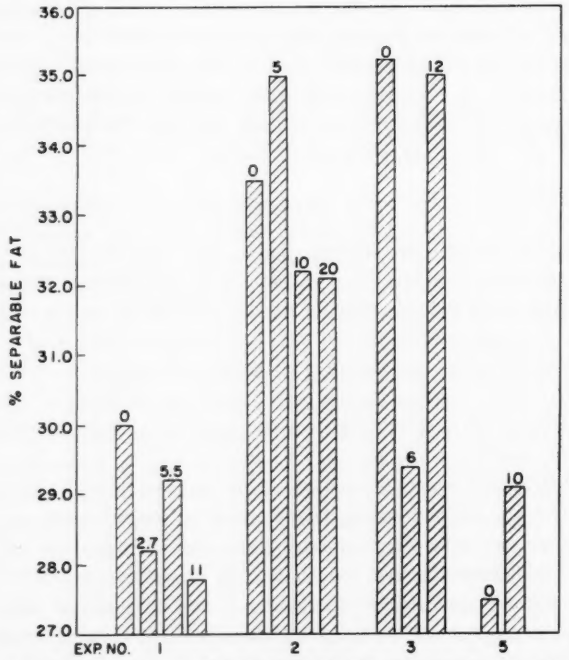

Figure 2. Percent separable fat in 9–10–11th rib cut based on total weight of cut.

carcass characteristics are given in figures 1–6. The number appearing above each bar indicates the average daily intake of diethylstilbestrol per animal. The number below each bar chart identifies the feeding experiment.

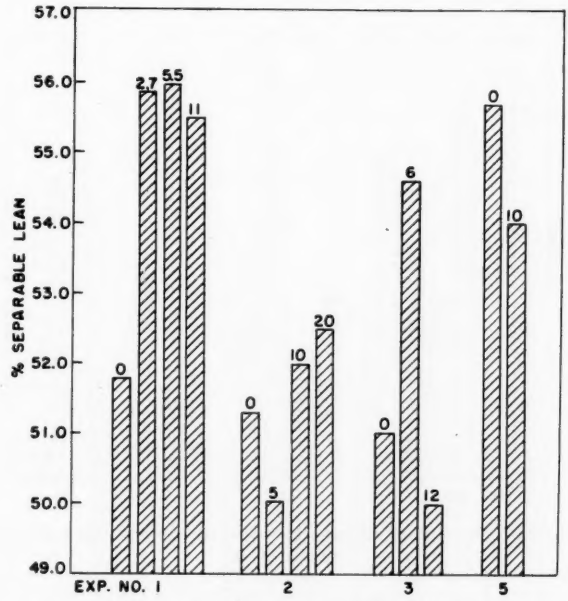

Figure 3. Percent separable lean in 9–10–11th rib cut based on total weight of cut.

These data show that the average live grades were higher than the carcass grades. The differences between grade were not consistent among lots or the experiments. The largest and most consistent differences between the live animal grades and carcass grades are to be found in the data for experiment 2 (figure 1). The graders expressed the opinion that the treated cattle had better looking hair coats than the controls, but no other outward differences in appearance of the animals were observed.

The bar charts in figures 2, 3, and 4 indicate that the fat, lean and bone composition of the rib cuts of carcasses of animals vary widely among experiments. These charts also indicate that the composition of

rib cut was not consistently related with amounts of diethylstilbestrol fed. The depth of fat over the 12th rib varied greatly among experiments, figure 5, and likewise was not consistently related with the feeding level of diethylstilbestrol. However, figure 6 shows that except for experiment 3 the cross sectional area of the longissimus dorsi muscles

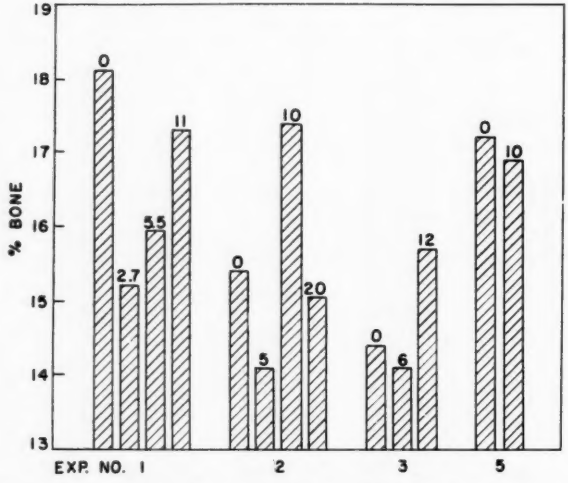

Figure 4. Percentage of bone in 9–10–11th rib cut based on total weight of cut.

of carcasses of treated animals were larger than that of the untreated animals. The standard deviations for the carcass data recorded in table 1 emphasize the large variability among carcasses of animals within lots.

An analysis of variance of the data was computed for each carcass characteristic for each experiment. The only mean differences among rations that were statistically significant, at the 5% level, were for bone content, rib-eye area, and hot dressed weight in experiment 1 and for rib-eye area and hot dressed weight in experiment 5. In addition, the mean difference between the control carcasses and the average of all carcasses from animals fed diethylstilbestrol was significant for lean content in experiment 1. None of the other mean carcass differences among rations approached statistical significance at the 5% level.

Since average daily gains were related with level of diethylstilbestrol fed in each experiment and since carcass characteristics were not con-

sistently related with level of diethylstilbestrol fed, a statistical study was made of the relationships between three carcass characteristics and rates of gain among animals within lots.

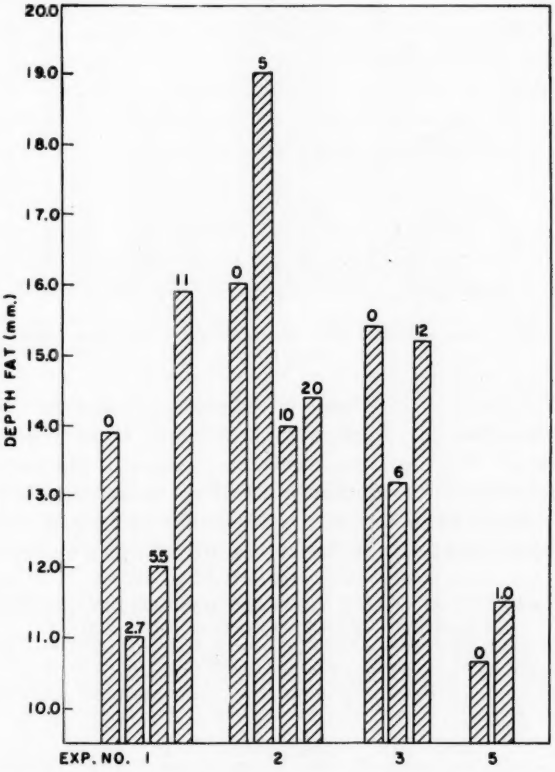

Figure 5. Depth of fat over the longissimus dorsi muscle at the 12th rib.

Correlation coefficients of average daily gain with carcass characteristics were computed for each lot in each experiment. They are presented in table 2. As a generalization, average daily gain was positively correlated with the fat content of the 9–10–11 rib cut and carcass grade.

The correlation coefficients of gain with carcass grade were all positive with one exception, lot 3, experiment 2, but only in one case was the correlation coefficient significant ($P<.05$) lot 1, experiment 5. Since

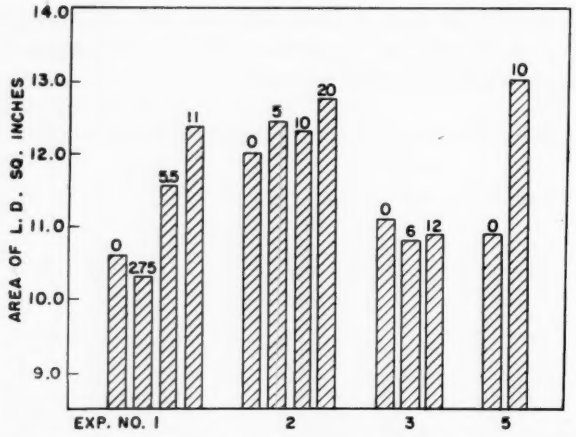

Figure 6. The cross sectional area of the longissimus dorsi muscle at the 12th rib.

similar basal rations were used in experiments 1 and 2, combined correlation coefficients of gain with these carcass characteristics were also computed. The correlation coefficients of gain with the fat content of the rib cut; with lean content of the rib cut and with grade for the controls were found to be 0.582, —0.534 and 0.450 respectively. The corresponding correlation coefficients for treated animals were 0.366,

TABLE 2. WITHIN LOT CORRELATION AND REGRESSION COEFFICIENTS OF CARCASS CHARACTERISTICS WITH GAIN

Exp. No.	Carcass charact.	Lot[a] 1		2		3		4	
		r	b	r	b	r	b	r	b
1	Fat	.492	4.72	.488	.437	—.442	—3.98	.775*	8.93*
	Lean	—.435	—4.21	.431	—.470	.543	3.73	—.137	—1.84
	Grade	.494	1.63	.027	.076	.010	0.03	.620	1.99
2	Fat	.666	6.15	.475	6.41	.550	6.02	.202	3.58
	Lean	—.680	—4.57	—.437	—5.74	—.513	—4.34	—.119	—1.19
	Grade	.409	1.04	.373	0.94	—.073	—0.34	.242	—0.50
3	Fat	—.064	—0.88	.522	2.65	.735	15.16		
	Lean	—.119	—1.41	—.427	—3.36	—.754	11.98		
	Grade	.457	0.89	.353	0.73	.493	0.98		
5	Fat	.060	0.67	.754*	11.67*				
	Lean	.049	—0.58	.599	—7.27				
	Grade	.771*	3.15	.518	3.09				

[a] Lot 1 is the control while lots 2, 3, and 4 identify the first, second and third levels of diethylstilbestrol fed (table 1).

* Significant at $P<.05$.

0.296 and 0.161. The correlation coefficients of gain with fat and with lean were significant ($P<.05$) for both controls and treated animals.

Discussion

The diethylstilbestrol implantation studies of Clegg and Cole (1954) on beef cattle suggest that animals receiving diethylstilbestrol may produce carcasses that are different in some respects at least, from those produced by animals not administered the drug. The present investigation failed to show that the feeding of diethylstilbestrol to beef cattle had any consistent effect upon carcass grades or the composition of the rib cut.

The correlations of carcass characteristics of animals within lots with rate of gain were higher than those for carcass characteristics with level of diethylstilbestrol fed. Whether this would be true for animals fattened for longer periods, i.e. fed to higher carcass grades or fattened to the same weight or for younger animals, cannot be predicted from these data.

An important observation was the large variation in carcass characteristics among animals within lots regardless of the amount of diethylstilbestrol fed. Furthermore those differences were in general larger than those among lots.

The conclusion drawn from these data does not infer that the feeding of diethylstilbestrol to beef animals produces no effect upon the carcass, for to accept this assumption is to conclude that effect upon the performance of the animal in the feed lot is without consequence to carcass tissues. In view of the large variations in the carcass characteristics among beef animals it would be necessary to study much larger numbers of animals in order to demonstrate whether or not diethylstilbestrol had any significant effect upon carcass composition.

Summary

Four investigations were made on 92 beef cattle in an attempt to determine whether orally administered diethylstilbestrol had any influence on carcass characteristics. The data failed to provide evidence that the feeding of diethylstilbestrol had any consistent influence on carcass characteristics as measured by carcass weight, grade, the fat, lean and bone content of the 9–10–11 rib cut, the area of the cross section of the longissimus dorsin muscle and thickness of fat over the rib-eye muscle. The variations in average daily gains of animals regardless of ration treatment were more consistently associated with

differences among a number of carcass characteristics. The correlation coefficients of carcass characteristics within lots with rate of gain were higher than those for carcass characteristics with level of diethylstilbestrol fed. The large differences observed among the various carcass attributes, while probably in part the consequence of nutritional treatments, appear to be related to some degree to inherent biological differences among animals which served as experimental subjects for these studies.

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EFFECT OF DIETHYLSTILBESTROL IMPLANTATION ON CARCASS COMPOSITION AND THE WEIGHT OF CERTAIN ENDOCRINE GLANDS OF STEERS AND BULLS [1, 2]

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THE apparent effect of diethylstilbestrol implantation on rate of gain and feed utilization of beef cattle has been recognized. (Burris *et al.*, 1953; Andrews *et al.*, 1954; Clegg *et al.*, 1954; Klosterman *et al.*, 1955). Naturally, the questions arise as to what physiological mechanisms might be responsible for these growth changes and what effects on carcass characteristics might result.

For efficiency in the industry, production and processing phase planning must be done with full cognizance not only of consumer desires but also of consumer acceptability of the product under consideration. This project was designed to study carcass characteristics as they influence value and acceptability at the wholesale, retail and consumer levels.

Procedure

Forty Herefords of similar breeding and age were used to provide four lots of 10 head each as follows: Lot I, Steers; Lot II, Steers implanted with stilbestrol; Lot III, Bulls; Lot IV, Bulls implanted with stilbestrol. These cattle weighed approximately 550 lb. when placed on feed and were marketed at about 16 months of age and at weights of 900 to 1000 lb. The hormone implantation in the ear consisted of 84 mg. at the beginning of the trial and again 84 days later at the midpoint of the feeding period.

Considerable slaughter data were obtained. Weights of pituitary, thyroid, brain, and adrenal glands were taken and the angle formed by the junction of the lumbar and sacral regions of the vertebral column was measured. On five carcasses of each lot wholesale cut weights were obtained and the right sides were separated into bone, fat in excess of three eighths inch thickness, and the remaining product identified as

[1] From a dissertation presented by V. R. Cahill to the Graduate School of The Ohio State University in partial fulfillment of the requirements for the Ph.D. Degree, 1955.

[2] Approved for publication by the Associate Director of the Ohio Agricultural Experiment Station as Journal Article No. 5-56.

edible portion. Taste panel scores were obtained on short loin steaks taken from the left sides of the same carcasses. These scores were based on a schedule of, "1. Very, very tough", to "10. Very, very tender". Data on 23 factors were analyzed statistically for significance.

Results

Table 1 contains pertinent slaughter information.

TABLE 1. COMPARISON OF SLAUGHTER AND GRADING DATA OF STEERS AND BULLS WITH AND WITHOUT STILBESTROL IMPLANTS

Item	Steers	Steers[a]	Bulls	Bulls[a]
Dressing percentage	61.6	61.6	61.0	61.6
Percent shrink[b]	4.3	3.5	2.6	3.1
Percent hide	7.8	8.6	8.9	8.7
Percent paunch	10.3	10.3	10.7	10.9
Carcass grade	Av. ch.	Low ch.	Av. gd.	High gd.

[a] Implanted with stilbestrol.
[b] Purchase weight to kill weight. Purchased on 6:00 a.m. weight (off feed and water overnight) less 3%. Trucked 90 miles the same day and slaughtered the next forenoon.

A study of endocrine glands revealed that the pituitary glands in the bulls and steers of this test were very similar in weight per unit weight of live animal. The pituitaries of steers and bulls weighed 0.208 gm. and 0.210 gm., respectively, per 100 lb. live purchase weight. Corresponding figures for implanted steers and implanted bulls were 0.226 gm. and 0.227 gm. per 100 lb. live purchase weight. Thyroid glands of these bulls were very significantly heavier than those of steers (2.752 gm. and 1.530 gm. per 100 lb. live purchase weight). Statistical analysis of the thyroid gland weights also indicates that the thyroids from the implanted bulls were significantly lower in weight than the normal bulls while thyroids of the implanted steers vary from the steers only slightly.

A comparison of adrenal glands shows practically the same weight in both steer and bull lots with a significant increase from the bulls, 1.610 gm. per 100 lb. live purchase weight to the 1.821 gm. of the implanted bulls. A similar difference occurred between the steers and implanted steers.

Pelvic Measurements

Investigation was made of the apparent effect of diethylstilbestrol implantation upon the structure of the skeleton in the pelvic region.

Of considerable note is the fact that the angle formed by the lumbar and sacral sections of the vertebrae was identical in measurement for the average of each of the untreated groups. This angle was of lower magnitude in the implanted groups and the difference was significant

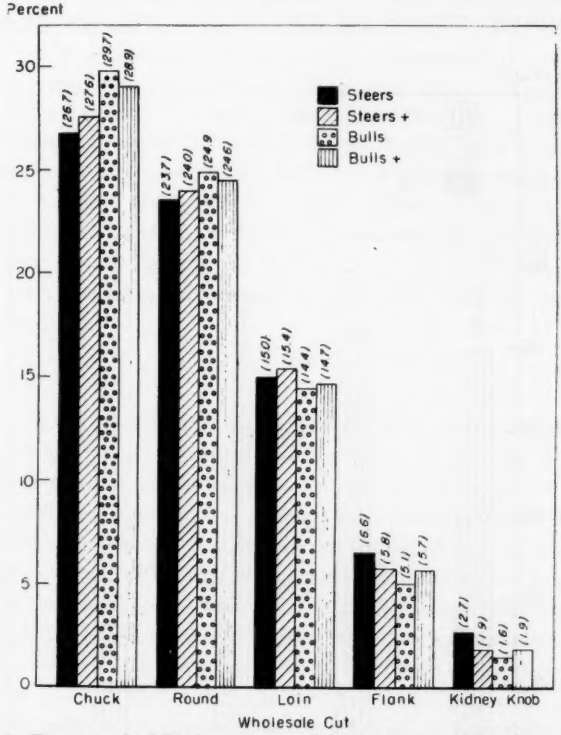

Figure 1. Percent of chilled carcass weight represented by five selected wholesale cuts.

at the 1% level. The more acute angles and higher tail heads were confirmed also by visual observation of the carcasses. This change in conformation did not appear to alter the sale value of the carcasses merchandised through the packing house cooler.

Wholesale Cuts

A study of wholesale cuts is presented graphically in figure 1. That the percentage of chuck in bull carcasses is highly significantly greater

than in steer carcasses is no new discovery but only confirmatory. It should be noted that in the case of chucks, implantation seemed to have a converse effect on steers and bulls. Attention may also be directed to the very similar pattern exhibited by the rounds. Although not statistically significant the percentage of loin end, short loin and rib from implanted carcasses was higher for both bull and steer lots. In

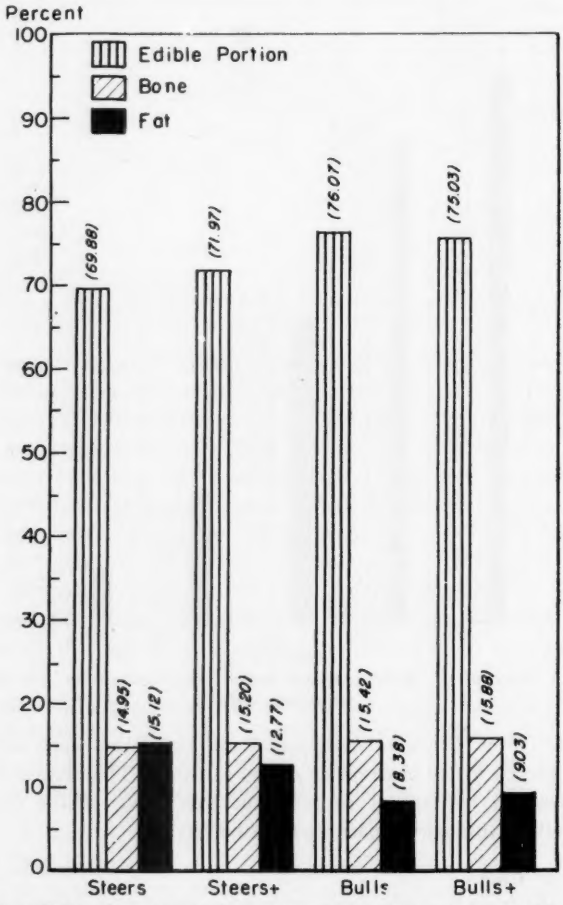

Figure 2. Percentage composition of the right sides summarized by lot.

addition, the percentage of short loin was greater in steers than in bulls, independent of treatment, to the point of being significant at the 1% level.

Considering the steers alone, the carcasses from implanted steers cut a higher percentage in all five of the more desirable wholesale regions than did carcasses of untreated steers. This 1.66% advantage is very nicely counterbalanced by a 1.61% decrease in the two least desirable wholesale cuts known as kidney knob and flank. One concluding observation is the wide variance in percentage of flank and kidney knob in untreated bulls versus untreated steers and the proximity of these percentages in implanted bulls and implanted steers resulting from the apparent reverse effect of diethylstilbestrol implants on the groups of animals. Based on percentage of carcasses, the bull flanks were highly significantly lighter than the flanks of the other three lots of cattle. Data concerning the kidney (organ) indicated little difference among the groups.

Physical Separation

The data are presented in figure 2. First, it is noted that the percentage of bone varies but little from the lowest, in the case of steers, to the highest in the implanted bulls. Fat, on the other hand, is widely variable and the lesser amount trimmed from the normal and treated bulls is significant at the 1% level in comparison with both groups of steers. Finally, the edible portion factor is statistically highly significant when the 76.1 and 75.0% of the bulls and implanted bulls are compared with the 69.9 and 72.0% found in the steer and implanted steer carcasses. Edible portion appears to be in an inverse relationship to the amount of fat and the analysis of variance shows the edible portion interaction factor to be significant at the 5% level. A direct relationship existed between the percentage of edible portion and area of longissimus dorsi muscle at the twelfth rib. The correlation coefficient was 0.853.

Tenderness Study

Unavoidable is the question: "If there is more meat to eat, how tender is it?" So far as this experiment is concerned, the data show that all carcasses were acceptable. The taste panel's score is presented in table 2.

TABLE 2. TENDERNESS SCORE

Lot	3 days post-mortem		13 days post-mortem	
	Mean	Standard dev.	Mean	Standard dev.
Steers	5.73	0.97	7.00	0.37
Implanted steers	5.68	0.79	6.82	0.75
Bulls	4.98	1.48	7.52	0.75
Implanted bulls	4.37	0.46	7.03	0.67

Contrast of Responses Observed in Bulls and Steers

Implantation of diethylstilbestrol pellets in steers and in bulls produced responses of varying degree. The data indicate that the steers and bulls responded in similar manner with reference to such factors as:

Variable	Implanted animals compared with untreated animals
Rate of gain	Increased
Weight of pituitary	Heavier
Weight of thyroid	Lighter
Weight of adrenal	Heavier
Weight of penis	Lighter
Elevation of tailhead	Pronounced
Weight of loin end	Heavier
Weight of short loin	Heavier
Weight of rib	Heavier
Percent bone	Greater
Tenderness	Less tender

Of these changes, only those of the thyroid, adrenal, penis (bulls only) and elevation of tailhead were shown to be statistically significant.

The reaction of steers to treatment differed from that of bulls when factors such as the following are considered:

Variable	Implanted steers compared with untreated steers	Implanted bulls compared with untreated bulls
Live shrinkage	Less	Greater
Weight of paunch	Less	Greater
Weight of hide	Greater	Less
Dressing percentage	Lower	Higher
Weight of chuck	Heavier	Lighter
Weight of round	Heavier	Lighter
Weight of flank	Lighter	Heavier
Weight of kidney knob	Lighter	Heavier
Area of long. dorsi	Greater	Smaller
Percent fat	Lower	Higher
Percent edible portion	Higher	Lower

As a result of treatment, changes which were statistically significant occurred in the weight of chuck and flank of both steers and bulls. The kidney knob of steers and area of the longissimus dorsi muscle of bulls were altered significantly by treatment. Although the alteration of amount of fat and edible portion did not show significance statistically, application of a dollar and cent value would make the difference of commercial importance.

Discussion

Consideration of endocrine gland weights of domestic animals apparently has received little attention. Christian (1953) observed a wide divergence in adrenal weights with respect to body weight between captive and wild rats and that confinement of wild animals frequently leads to relative adrenal atrophy. However, data gathered on many species showed that the adrenal gland weights follow a definite logarithmic relationship to body size for all species examined and this relationship parallels that of a single species over a wide age and weight range.

In this experiment the pituitary and adrenal glands from cattle treated with stilbestrol were larger than those from untreated animals. This is in agreement with Clegg *et al.* (1951) who reported similar results. Stilbestrol treatment resulted in a decrease in weight of thyroid glands and this change was especially significant in the case of bulls.

Explanation of the cause of increased rate of gain apparently is not fully understood. Clegg and Cole (1954) indicated that no significant difference in the content of the growth hormone and ACTH in the pituitaries of treated steers was found. Histological study of the pituitary glands from this project is being made by the Department of Anatomy at The Ohio State University. Preliminary studies indicate that the basophil count varies inversely with rate of gain.

Numerous reports (Clegg and Cole, 1954 and Andrews *et al.*, 1954) have indicated a lowering of carcass grade as a result of subcutaneous treatment of steers with diethylstilbestrol. Dinusson *et al.* (1950) and Andrews *et al.* (1950) noted no significant difference in carcass grade or dressing percentage.

It is of interest to note grade comparison in these data. Implantation resulted in one-third grade lower steer carcasses but actually raised the bull carcasses from average good to high good. In a review of diethylstilbestrol work Winchester and Andrews (1953) conclude that lower carcass grade results from reduced subcutaneous fat. Conversely, it is

the increased subcutaneous fat on implanted bull carcasses along with the excellent muscular development that qualifies them for the higher grade. The tendency for more fat to be deposited internally and subcutaneously on implanted bull carcasses is reflected by the weight of flank and kidney knob. A second effect of implanting bulls is a retarding of the development of secondary sex characteristics. This is evidenced by the decrease in weight of testicles, penis, and hide. Perhaps a combination of these effects and the increase in flank and kidney knob are responsible for the decrease noted in percent chuck of implanted bull carcasses.

Although the number of carcasses involved in the tenderness study is not sufficiently large to draw definite conclusions, the tendency is of more than passing importance. The increase in tenderness from 3 days post-mortem to 13 days post-mortem and the similarity of tenderness of beef from all four lots at 13 days may serve as a guide for further investigations. Unpublished data of the authors on tenderness covering a much larger sample support the observations made in this report.

Summary

Forty Hereford cattle were allotted to four groups of 10 head each. These lots consisted of steers, implanted steers, bulls and implanted bulls. The subcutaneous implantation in the ear of 84 mg. of diethylstilbestrol was made at the beginning of the feeding period and again 84 days later.

Treatment of steers lowered the carcass grade; treatment of bulls produced carcasses of higher grade. From the implanted cattle slightly heavier pituitary glands and significantly heavier adrenal glands were obtained. Thyroid glands of the implanted bulls were significantly lighter in weight than the same gland of the untreated bulls but treatment of steers had little effect on the weight of this gland. Measurement of the lumbo-sacral angle gave evidence that treatment made this angle much more acute.

Implanting of bulls increased the percentage of fat while the reverse appeared to be true in the case of the steers. In comparison, the 76.7% edible portion found in bull carcasses was lowered to 75.0% in the carcasses from treated bulls. Implantation raised the edible portion from 69.9% in the untreated steers to 72.0% in the treated steers. Measurement of the cross section area of the longissimus dorsi muscle correlated directly with the edible portion data. An organoleptic test at 13 days post-mortem indicated only slight differences in tenderness.

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EFFECTS OF CHLORTETRACYCLINE, INEDIBLE ANIMAL FAT, STILBESTROL AND HIGH AND LOW QUALITY ROUGHAGE ON PERFORMANCE OF YEARLING STEERS

I. FEED CONSUMPTION AND RATES OF GAIN

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CHLORTETRACYCLINE has been shown by many workers to increase rates of gain and efficiency of feed utilization in swine and poultry. Similar results with immature ruminants have also been well established. Loosli and Wallace (1950), Jacobson *et al.* (1951), Knodt *et al.* (1953), McKay *et al.* (1952) and many others have reported increased rates of gain of dairy calves fed chlortetracycline. The results of feeding this antibiotic to mature ruminants, however, has not consistently resulted in improved performance. Neumann *et al.* (1951) reported that chlortetracycline had no beneficial effect on performance of beef heifers fed a fattening ration composed of corn silage, ground yellow corn, linseed meal, and salt. Bridges *et al.* (1953) fed chlortetracycline at levels ranging from 1.1 to 15 mg. per pound of feed in various trials, with lambs weighing 56–64 lb., without significantly influencing rates of gain. Jordan (1952), working with lambs, also reported that a high level of chlortetracycline (14.4 mg.) per lamb daily, included in a ration composed of alfalfa hay, shelled yellow corn and soybean meal, reduced rates of gain, however, lower levels had a slightly beneficial effect. Colby *et al.* (1950) fed lambs 100 mg. of chlortetracycline daily, by capsule, and reported a reduction in rates of gain as compared with the control group. This work involved the use of ex-

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cessive amounts of chlortetracycline along with a method of administration now known to be unsatisfactory.

Conversely, Perry *et al.* (1953) reported an increase in rates of gain and feed efficiency when 15 mg. of chlortetracycline per pound of concentrate was fed to yearling steers and heifers. Their ration was composed of corn, oats, soybean meal with hay fed free choice. It is apparent from the literature that chlortetracycline exerts different effects under different nutritional regimes. The stage of rumen development as related to rumen biota and the type of ration fed appears to influence the effects of chlortetracycline on ruminants.

Because of the present surplus of inedible fats, interest has increased in relieving this surplus through livestock feeding. Willey *et al.* (1952) working with steers reported an increased feed efficiency when fat was added to their respective rations. Moreover, Jones *et al.* (1942) found that the addition of cottonseed oil to cattle rations exerted a beneficial effect on the rate of gain. Beneficial effects of fat in ruminant feeding was reported by Matsushima *et al.* (1954) when corn oil and beef tallow was fed to fattening steers. Hentges *et al.* (1954) in a 90-day feeding trial with yearling steers fed 5% tallow, observed a faster rate of gain with increased feed efficiency. Another trial with 8 months old steers fed 5 and 10% added fat resulted in maximum feed efficiency with 5% added fat. Schweigert and Wilder (1955) reported that 1 lb. of fat can replace 2.5 lb. of corn for steers fed a fattening ration. The use of animal fat in ruminant rations has not been elucidated to the point where its use can unequivocally be recommended for all types of rations.

Diethylstilbestrol incorporated in the ration of fattening steers at levels of 5–10 mg. per head daily has generally resulted in increased rates of gain and efficiency of feed utilization (Burroughs *et al.*, 1954; Luther *et al.*, 1954; Perry *et al.*, 1955 and others). Similar responses have been reported when stilbestrol was implanted. Implantation of 60 or 120 mg. per steer, however, has resulted in certain undesirable side effects including uneven top lines, excessive mammary development and reduced carcass quality (Andrews *et al.*, 1954).

The mode of action of stilbestrol has not been definitely established. However, it appears plausible that the accelerated gains may be mediated through an increased digestion of crude fiber (Brooks *et al.*, 1954). Irrespective of reported increases in crude fiber digestion, the possible metabolic role of stilbestrol cannot be discounted. Steinglass *et al.* (1941) reported that the normal hemoglobin and red cell count

in the female is lower than in the male rat. After castration, a decrease in the above fractions in males and an increase in females was found. Androgen administration stimulated while estrogens depressed erythropoiesis. Reduced hemoglobin levels and increased rates of gain were reported by Clegg and Cole (1954) when stilbestrol was implanted into steers fed on various dietary regimes. The suggestion was made by Meyer *et al.* (1940) that hematopoiesis was not dependent upon a specific hormone but due to a metabolic change.

Procedure

Forty-eight yearling Hereford steers were randomly allotted to a 2^4 factorial experiment consisting of 16 groups of 3 steers each. Chlortetracycline, fat (bleachable fancy tallow), stilbestrol and roughages (alfalfa and wheat straw) were the variables. Steers were individually fed an all-pelleted ration twice daily for 183 days. Feed consumption was recorded for each animal. The composition of the various rations is presented in table 1. Water was available in automatic waterers at all times. Weights were recorded at 28-day intervals. Average daily gains were analyzed as a 2^n factorial series by the method outlined by Kempthorne (1952). Blood was drawn from all steers four times during the experimental period and subjected to hemoglobin and hematrocit determination.

TABLE 1. COMPOSITION OF THE PELLETED RATIONS FED TO THE 16 GROUPS (3 STEERS PER GROUP)

Ingredients	Rations fed to groups [a]			
	1, 3, 5, 7	2, 4, 6, 8	9, 11, 13, 15	10, 12, 14, 16
Alfalfa hay	..	50	..	82
Wheat straw	50	..	82	..
Fat	..	..	7	7
Molasses	10	10	..	..
Barley	18	18.75	4.50	5.25
Milo	6	6.25	1.50	1.75
Oats	4.67	4.67	.73	1
Beet pulp	9.32	9.32	1.47	2
Salt	1	1	1	1
Urea	1.00	..	1.80	..
Crude protein, %	7.74	10.35	6.44	10.88
Crude fiber, %	23.60	18.30	34.80	25.40
Ether extract, %	1.25	1.50	7.14	7.35
Dry matter, %	87.80	87.40	88.40	87.50

[a] Groups 5, 6, 7, 8, 13, 14, 15, and 16 received 5 mg. chlortetracycline per pound of feed. Groups 3, 4, 7, 8, 11, 12, 15, and 16 received 0.45 mg. of stilbestrol per pound of feed.

TABLE 2. EFFECTS OF FEEDING INEDIBLE ANIMAL FAT, STILBESTROL, AND CHLORTETRACYCLINE ON RATES OF GAIN AND FEED REQUIRED PER POUND OF GAIN (183) DAYS

Treatment Groups[a]	No. of steers	Average initial wt.	Feed per lb. gain	Av. feed per steer per day	Av. daily gain, lb.			Treatment effects[a]	Av. daily gain, lb.		
					60 days	133 days	183 days		60 days	133 days	183 days
		lb.	lb.	lb.							
(1)	3	559	14.9	14.8	1.09	1.37	1.06	Mean	0.97	1.04	0.98
(a)	3	601	15.2	13.2	0.74	1.01	0.89	A	0.63**	0.41**	0.62**
(s)	3	604	13.8	18.0	0.68	1.23	1.31	S	−0.09	0.04	0.14
(as)	3	593	12.5	13.0	0.82	0.82	1.01	AS	0.19	0.02	0.13
(c)	3	587	12.2	16.8	0.92	1.27	1.38	C	0.36	0.25	0.27**
(ac)	3	639	18.0	14.9	1.14	0.94	1.00	AC	0.13	−0.04	−0.05
(sc)	3	601	13.4	17.2	0.89	1.60	1.34	SC	0.15	0.20	−0.04
(asc)	3	589	9.9	14.3	1.17	1.27	1.44	ASC	0.03	−0.05	−0.04
(f)	3	589	....	14.2	0.35	0.24	−0.03	F	0.08	−0.28*	−0.41**
(af)	3	593	12.3	14.6	1.43	1.36	1.29	AF	0.58**	0.76**	0.78**
(sf)	3	607	....	11.8	−0.02	−0.03	−0.26	SF	0.01	−0.03	−0.08
(asf)	3	586	10.7	15.6	1.20	1.38	1.45	ASF	0.05	0.26*	0.02
(cf)	3	583	50.0	13.9	0.77	0.43	0.28	CF	0.18	−0.08	0.07
(acf)	3	589	9.6	13.8	1.69	1.56	1.46	ACF	−0.05	−0.06	−0.07
(scf)	3	585	44.3	14.0	0.48	0.63	0.33	SCF	0.06	−0.06	0.05
(ascf)	3	589	8.8	14.8	2.21	1.66	1.70	ASCF	0.14	−0.05	−0.09
								* $LSD_{.05}$	0.44	0.26	0.18
								** $LSD_{.01}$	0.59	0.35	0.24

[a] (1) straw; (a) alfalfa; (s) stilbestrol; (c) chlortetracycline; (f) fat.

Results and Discussion

Table 2 shows means for average daily gains and feed required per pound of gain of the steers on various treatments. This table also shows treatment effects resulting from the various rations fed. Chlortetracycline fed at 5 mg. per pound in the rations ranging from 50 to 83% roughage resulted in a highly significant increase in rates of gain. This increase was consistent within treatments throughout the experiment. A difference of 0.22 lb. per steer daily occurred as a result of adding this antibiotic to the "alfalfa" rations, whereas a difference of 0.31 lb. was observed in the "straw" rations. Chlortetracycline, however, did not significantly affect either the amount of feed consumed or the efficiency of feed utilization. It is possible that the antibiotic supported more rapid weight gains partially through an alteration of the rumen microflora. Hungate *et al.* (1955) demonstrated that as little as 5 mg. of chlortetracycline per pound of feed modifies the rumen biota. Steers fed chlortetracycline consumed 0.5 lb. of feed per head daily more than those not receiving this antibiotic.

The addition of 7% fat (bleachable fancy tallow) significantly increased ($P<.01$) rates of gain of the steers fed the pellets containing alfalfa. This same level of fat significantly reduced ($P<.01$) the rates of gain of steers consuming wheat straw rations during the 183-day feeding period. The reduction was such that the over-all effect of fat among the various rations was to significantly depress the rate of gain. This difference cannot be explained on the basis of the amount of energy in the various rations. Since fat tended to reduce crude fiber breakdown these differences apparently may be explained in that wheat straw has a higher crude fiber content than does alfalfa (Morrison, 1954).

Stilbestrol fed at the rate of 0.45 per pound of ration did not significantly increase either the rates of gain or feed required per pound of gain of yearling steers over those of similar steers not fed stilbestrol. An average increase of only 0.14 lb. per steer daily was observed as a result of adding stilbestrol. A difference of 0.26 lb. per steer daily favoring the stilbestrol-fed groups occurred when alfalfa was fed. This difference was not significant. Stilbestrol was perhaps too low at first because the pelleted rations were unpalatable; and consumption averaged approximately 12 lb. of feed (5.4 mg. stilbestrol) per steer daily. After approximately 60 days, average consumption began increasing until an average of approximately 23 lb. (10.4 mg. stilbestrol) per steer was

eaten at the close of the experiment. No undesirable side effects as a result of feeding stilbestrol were observed.

As would be expected, the rations containing alfalfa produced a significantly faster rate of gain ($P<.01$) than those containing the wheat straw. Either the higher mineral, vitamin or energy content of the alfalfa, or a combination of these factors could have been responsible for this difference. A significant interaction of roughage and fat occurred. Fat fed with alfalfa accelerated rates of gain but reduced rates of gain of steers on the wheat straw rations.

Hemoglobin and hematocrit values were not significantly influenced by treatment. More difference occurred within groups than between groups. Stilbestrol resulted in no significant influence on either the rate of gain or hematopoiesis.

Summary and Conclusions

Forty-eight yearling, grade Hereford steers were allotted to a factorial experiment in which roughages (alfalfa and wheat straw), chlortetracycline, fat and stilbestrol were the variables. Individual feeding these steers for 183 days indicated that:

1. Chlortetracycline significantly increased rates of gain in rations with alfalfa or wheat straw.
2. Fat increased rates of gain of steers consuming alfalfa but reduced rates of gain of straw-fed steers.
3. Stilbestrol had no significant effect on either rates of gain or on feed required per pound of gain.
4. No apparent undesirable side effects were produced as a result of feeding stilbestrol.
5. No interaction between chlortetracycline and stilbestrol was found.
6. Neither hemoglobin nor hematocrit values were affected by the treatments imposed in this experiment.

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EFFECTS OF CHLORTETRACYCLINE, INEDIBLE ANIMAL FAT, STILBESTROL AND HIGH AND LOW QUALITY ROUGHAGE ON PERFORMANCE OF YEARLING STEERS

II. DIGESTIBILITY OF DRY MATTER, CRUDE FIBER, CRUDE PROTEIN, AND ETHER EXTRACT

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MUCH of the energy derived from ruminant rations is in the form of volatile fatty acids resulting from a breakdown of starch and cellulosic material in the rumen. Hungate *et al.* (1955) reported that chlortetracycline alters the rumen biota. Bell *et al.* (1950) demonstrated reduction in cellulose and dry matter digestion by steers as a result of adding 200 mg. of chlortetracycline daily to a ration composed of corn, soybean oil meal and prairie hay. Horn *et al.* (1955), also working with steers, reported a decrease in the digestion of protein and crude fiber as a result of adding chlortetracycline. Other workers, Pritchard *et al.* (1955); Murley *et al.* (1952); and Chance *et al.* (1953), have indicated that chlortetracycline does not have a depressing effect on the digestibility of crude fiber.

Only fragmentary data are available on the effect stilbestrol exerts on digestibility of the various nutrients in the rations of ruminants. Clegg and Cole (1954) reported that the nitrogen retention by steers implanted with stilbestrol was almost doubled. Brooks *et al.* (1954) reported an increase in cellulose digestion *in vitro* and *in vivo* in the presence of stilbestrol.

Brooks *et al.* (1954) reported that fat reduced the digestion of cellulose *in vitro*. This could have a marked effect on the value of added fats in ruminant rations since a large part of their feed is composed of cellulosic materials. Swift *et al.* (1948) stated that the digestibility of fat was increased as the level of fat in the ration of sheep was increased. They further indicated a trend toward a decrease in the digestibility of dry matter with the increase of fat in the ration.

Because of a general lack of agreement in the literature, this experiment was conducted to determine what effects chlortetracycline, stilbestrol, and fat fed singly and in combination have on the apparent digestibility of certain nutrients in ruminant rations.

[1] Scientific Paper No. 1445, Washington Agricultural Experiment Stations. Project No. 1217.

Procedure

The 16 groups of 3 steers each were treated as described by Erwin *et al.* (1956). Digestibilities of dry matter, crude fiber, crude protein, and ether extract were determined by the lignin ratio technique of Ellis *et al.* (1946), with slight modifications. The data obtained were subjected to statistical analysis as described by Kempthorne (1952).

TABLE 1. EFFECTS OF FEEDING INEDIBLE ANIMAL FAT, STILBESTROL AND CHLORTETRACYCLINE ON DIGESTIBILITY OF DRY MATTER, CRUDE PROTEIN, CRUDE FIBER AND ETHER EXTRACT (3 ANIMALS PER GROUP—EACH INDIVIDUALLY FED)

Treatments[a]	Average initial wt.	Av. daily gain	Coefficients of digestibility, %[b]			
			Dry matter	Crude prot.	Crude fiber	Ether extract
	lb.	lb.				
1. (1)	559	1.06	65.02	65.50	47.20	80.53
2. a	601	.89	70.54	72.03	40.93	64.57
3. s	604	1.31	70.45	73.30	56.93	76.88
4. as	593	1.10	71.71	69.00	53.97	60.73
5. c	587	1.38	66.13	71.34	54.97	75.74
6. ac	639	1.00	73.51	65.85	48.50	60.57
7. sc	601	1.34	65.89	61.33	56.92	78.45
8. asc	589	1.44	72.07	63.37	48.58	60.05
9. f	589	—.03	42.46	64.16	37.70	90.89
10. af	593	1.29	63.23	65.05	45.15	89.67
11. sf	607	—.26	46.55	69.67	35.50	87.79
12. asf	586	1.45	61.87	65.58	44.40	87.30
13. cf	583	.28	43.72	69.92	30.45	80.31
14. acf	589	1.46	60.79	69.12	37.10	81.13
15. scf	585	.33	44.90	71.55	38.30	87.53
16. ascf	589	1.70	60.43	59.85	24.15	82.59

[a] (1) straw; a, alfalfa; s, stilbestrol; c, chlortetracycline; f, fat.

[b] Appreciation is expressed to Troy Scott, Agricultural Chemistry, State College of Washington for determination of lignin in the feed and feces.

Results and Discussion

The digestibility of the dry matter, crude fiber, crude protein, and ether extract is presented in table 1. Analysis of these data (table 2) indicates that chlortetracycline significantly decreased the apparent digestibility of the ether extract. A statistically insignificant decrease in digestibility of protein, dry matter and crude fiber occurred in the presence of chlortetracycline. The rates of gain were significantly increased in the antibiotic-fed groups. This increase in rate of gain cannot be explained on the basis of digestibility of the above nutrients.

According to Hungate *et al.* (1955), certain of the microorganisms apparently select themselves on the basis of their resistance to chlortetracycline and are at least equally as active in the presence of this antibiotic. Any improvement in performance as a result of added chlortetracycline might be mediated through microbial activity, but it does not appear to be by means of increased digestion.

TABLE 2. MAIN AND INTERACTION EFFECTS OF THE VARIOUS TREATMENT COMBINATIONS OF DIGESTIBILITY

Treatment[a]	Dry matter	Ether extract	Crude protein	Crude fiber
Mean	61.2	77.8	67.2	43.8
A	11.1**	−8.9**	−2.6	−1.9
S	1.1	−0.3	−0.9	2.1
AS	−1.6	−1.1	−2.2	−2.2
C	0.6	−4.0*	−1.3	−2.8
AC	0.4	−0.5	−1.6	−3.7*
SC	−1.4	3.0	−4.1*	−2.9
ASC	0.9	−1.2	1.3	2.1
F	−16.4**	16.2**	−0.6	−14.4**
AF	6.0**	−7.5**	−1.6	4.1*
SF	−0.2	1.1	0.5	−4.1*
ASF	−0.2	−0.2	−1.8	−2.6
CF	−0.5	−2.1	2.7	−5.3**
ACF	−1.4	−0.1	−0.7	−2.3
SCF	0.8	−0.6	0.7	2.3
ASCF	0.9	−0.4	−2.8	3.4
*$LSD_{.05}$	2.08	3.04	3.84	3.59
**$LSD_{.01}$	2.80	4.08	5.15	4.82

[a] A, Alfalfa; S, Stilbestrol; C, Chlortetracycline; F, Fat.

The addition of 7% fat (bleachable fancy tallow) significantly ($P<.01$) reduced the digestibility of dry matter and crude fiber by steers fed both the alfalfa and straw type rations. The digestibility of the added fat was significantly higher than the ether extract present in the ration. These data corroborate the reports of Lucas and Loosli (1944), and Swift *et al.* (1948). The latter showed an increase in the digestibility of ether extract in the ration when fat was added. They also reported a lower digestibility of dry matter upon the addition of fat to the ration of sheep.

The mode of action of fat in reducing the digestibility of certain nutrients in the ration has not been definitely established. A possibility exists that the depressing effect is physical—that is, by coating the

fiber so that the cellulolytic microorganisms cannot freely degradate the fiber.

Stilbestrol included in the ration at .45 mg. per lb. of feed did not significantly influence the digestibility of either the dry matter, crude fiber, ether extract or crude protein in the ration. Mean digestibilities on the stilbestrol versus the non-stilbestrol fed steers for each of the above four nutrients were almost identical. There was a significant interaction between type of roughage and fat in decreasing the digestibility of ether extract, dry matter and crude fiber (table 2). Significant interactions between fat and stilbestrol, and fat and chlortetracycline in reducing the digestibility of crude fiber also occurred.

Summary and Conclusions

Forty-eight steers were individually fed in a factorially designed experiment to determine the effects of chlortetracycline, stilbestrol, fat, and roughage on digestibilities of dry matter, crude fiber, ether extract, and crude protein.

Using the lignin ratio technique, under the condition of this experiment, it was found that chlortetracycline significantly decreased the digestibility of ether extract. Fat, fed as 7% of the ration, significantly reduced the digestibility of dry matter and crude fiber but increased the digestibility of ether extract. Stilbestrol did not influence the digestibility of either the dry matter, crude fiber, crude protein or ether extract. A higher digestibility of dry matter occurred in groups fed the alfalfa rations than in those fed wheat straw. The digestibility of ether extract was higher in straw-fed steers than in steers fed the alfalfa ration. The mode of action of chlortetracycline, stilbestrol, or fat in either increasing or decreasing digestibility was not determined.

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WATER INTAKE RATES OF CATTLE

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IN areas of limited water supply, quantitative information on water intake rates of farm animals is comparable in importance to information on the animals' other nutrient requirements. Published data on water intake rates of various species of farm animals have been reviewed by various workers but apparently tables of water intake of cattle under a variety of conditions of ambient temperature, body size, and level of feed intake have not been compiled. The prediction of the water intake of a single animal or of a few head of cattle is not possible due to the wide difference that exist between the intake levels of individuals, or even between the levels ingested by a given animal on consecutive days, under apparently like conditions. On the other hand, the probable intake of a large number of animals under a given set of conditions can be estimated with a fair degree of confidence. We began this study in response to requests by livestockmen, engineers and others for information for practical use on water consumption of herds of cattle. Because of the urgency of the need for information and the fact that many persons have asked us to make available without delay any facts pertinent to the water requirements of cattle, our estimates have been based upon such data as are presently available rather than upon extensive original data compiled over a period of years. Some terms describing the amounts of water ingested that must be defined before a discussion of the water needs of farm animals can be undertaken are the following: 1. "Water consumption" represents the "free water" drank by an animal. 2."Total water intake" includes both the water drank and that contained by the feed. 3. "Water requirement" is the equivalent of the water from all sources, including that of metabolism, necessary to maintain the water balance.

Sources of Information

Ritzman and Benedict (1924) observed that rate of water intake is a function of dry matter consumption and on the basis of this observa-

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tion Leitch and Thompson (1944) attempted a correlation of the two. However, after a careful study the latter workers concluded that water intake cannot be predicted satisfactorily upon the basis of the dry matter ingested. They used as their basic information data recorded under a variety of experimental conditions by various workers who in most cases had not reported the environmental temperatures that prevailed during their trials; therefore temperature, although recognized by Leitch and Thompson as a factor influencing water intake, was not taken into consideration in their study. In making their calculations, they were careful to select only such data as were recorded under conditions, such as those prevailing during digestion trials, in which such data as the type and amount of feed ingested and the water consumption are recorded. Their reasons for excluding many data from their calculations are as follows: "Most of the estimates of water requirements that have been found are of a general nature: such as that a cow, or other animal, will *drink* so many gallons of water daily, without specifying the conditions under which those amounts of water will be drunk and regardless, for instance, of the fact that, on a diet with a high proportion of succulent roots, a cow may not drink at all. Those authors who do record accurate observations on water consumption usually fail to give data on all the associated conditions which determine requirements, such as the type or the amount of the ration used, or the temperature at which the observations were made."

A large part of the information on water intake rates of farm animals that appeared prior to the publication of their report was reviewed by Leitch and Thompson (1944), while much of the information that has become available more recently has been summarized by Sykes (1955) who has included, in his report, tables giving ranges of water consumption that make possible the estimation of maximal intake rates. Because the subject either was reviewed or summarized in these papers, the bulk of the literature pertaining to rates of water intake will not be reviewed here.

In contrast with the information available a decade ago, reports have appeared within recent years in which water consumption has been given together with information on feed intake, environmental temperature and other relevant factors (Brody *et al.*, 1954; Ittner *et al.*, 1951, and 1954; Kelly *et al.*, 1955; Ragsdale *et al.*, 1950, 1951, 1953). These reports include information on dairy cattle in constant temperature chambers, on beef cows under various regimens in the Imperial Valley of California at a mean temperature of 90° F., and some material on

Indian cattle *(Bos indicus)*. These data plus a small amount of hitherto unpublished information on feed and water consumption of some cattle used in nutrition studies at Beltsville, Maryland, comprise the basic data used in making our estimates. The last mentioned group of animals consisted of 3 pairs of monozygotic twins including one pair each of steer and heifer Milking Shorthorns and a pair of Hereford × Guernsey heifers.

Analytical Methods and Results

To determine whether or not the ambient temperature-dry matter consumption-water intake relationship can be used to estimate water intake of cattle, the ratios of water intake per unit of dry matter ingested at various ambient temperatures were calculated on the basis of the data we have described. These calculations made apparent the existence of 2 distinct curves representing water intake rates respectively of European and Indian cattle.

Estimation of Water Intake Rates

The rate of water intake per unit of dry matter ingested remains relatively constant from around 10° to 40° F. and then increases with ambient temperature at an accelating rate. In figure 1 are given mean values of total water intake in gallons per pound of dry matter ingested at 40° to 100° F. together with the standard deviations of the means as indices of the distribution of the datum points in relation to the mean values. With a single exception, the data used in the calculations consisted of mean intake rates of *individuals* over a period roughly of one or two weeks. The exception was the information on beef cattle at 90° F. which was recorded originally as group data. In every case means were weighted regarding the numbers of individuals involved, but in calculating the standard error at 90° it was necessary to treat each of the 4 numbers representing seasonal means of groups of 4 to 10 beef animals as though they represented merely the intake of individuals. Perhaps the standard error would have been somewhat *larger* than that given for 90° in figure 1 if information on individuals instead of groups had been used.

In addition to any other value they may have, the standard deviations serve as a basis of judgment as to whether or not the data constitute two distinct curves or one.

The curves shown in figure 1 were obtained by fitting orthogonal polynomials (Fisher and Yates, 1948). This method is based on the

assumption that the values of the dependent variable, Y, are of equal weight, *i.e.*, that the number of animals on which calculations are based is the same at each temperature. This was not true of the data used in calculating the polynomial equation for European cattle; these data were

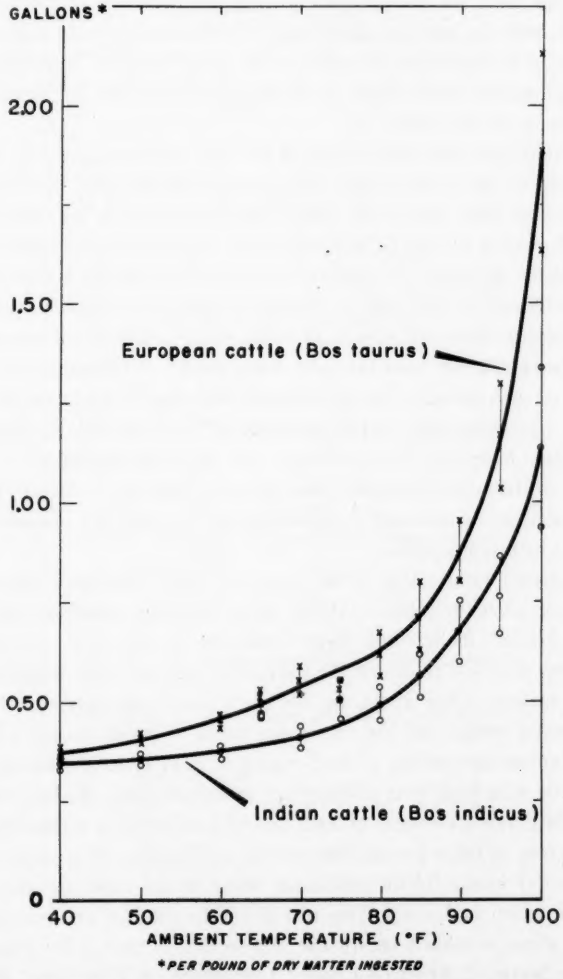

Figure 1. Water intake expressed as a function of dry matter consumption and ambient temperature.

of unequal weight. Data recorded at 65, 75, 85, and 95° F. are shown in figure 1 but were not used in calculating the equations because their inclusion would have meant that values of the dependent variable would not have been given for equal intervals of the independent variable. That this does not detract greatly from the accuracy of the curves is evident from the fact that at 65° and 75° data on relatively only a small number of animals were recorded, while at 85° and 95° with the exception of data on Indian cattle at the latter temperature the mean points fall exactly on the curves.

In addition to the water excreted in urine and feces and lost through evaporation, the water output of lactating cows includes, of course, the water of the milk, and, if the relationships concerned in the water intake of such cows are to be established, some method must be used to compensate for the water contained in the milk. Because the water required for production of milk must be ingested in addition to water for the other physiological needs, an amount of water equal to this added requirement must be subtracted from the total water intake of lactating cows if the intake of such animals is to be compared with that of nonlactating cattle. Leitch and Thompson (1944) estimated 87% of the milk, by weight, to be water. Following this precedent, we have subtracted 87% of the weight of the milk, produced, from the water ingested by lactating cows; the remainder is assumed to represent water intake for purposes other than its inclusion in milk.

Estimated total water intake rates of cattle of various classes and sizes are given in table 1. While these estimates expressed as "total water intake" include the water contained by the feed, for practical purposes they also represent the water that animals drink when fed such "dry" rations as hay and grain. On such rations the difference between total water intake and the free water drank does not exceed 0.3 gallon a day unless the amount of feed consumed is as large as that consumed by a cow at a high level of lactation, and even when the feed intake is high the difference seldom exceeds half of a gallon. The estimated intake rates given in table 1 were obtained by multiplying the estimated daily dry matter intake by the calculated water intake rates per unit of dry matter shown in figure 1. Dry matter intake rates of cattle in all categories given in table 1 except the first section of part 2 are those given by the National Research Council Committee on Nutritional Require-

ments of Farm Animals (Loosli *et al.*, 1950 and Guilbert *et al.*, 1950). Dry matter intake rates of animals in the first section of the second part of the table, namely "cattle on maintenance rations," have been esti-

TABLE 1. TOTAL DAILY WATER INTAKE[a]

(Part 1—Dairy Cattle)

Temperature (Fahrenheit)				40°	50°	60°	70°	80°	90°
Gallons of water per pound of dry matter				0.37	0.40	0.46	0.54	0.62	0.88
	Expected daily gain								
Body weight	Small breeds	Large breeds	Dry matter daily						
lb.	lb.	lb.	lb.	gal.	gal.	gal.	gal.	gal.	gal.
			Heifers						
100	1.0	0.8	1.8	0.7	0.7	0.8	1.0	1.1	1.6
200	1.4	1.6	5.4	2.0	2.2	2.5	2.9	3.3	4.8
400	1.2	1.8	9.9	3.7	4.0	4.6	5.3	6.1	8.7
600	0.8	1.4	13.5	5.0	5.4	6.2	7.3	8.4	11.9
800	1.1	1.2	17.1	6.3	6.8	7.9	9.2	10.6	15.0
1000	...	1.3	19.8	7.3	7.9	9.1	10.7	12.3	17.4
1200	...	1.2	21.6	8.0	8.6	9.9	11.7	13.4	19.0
			Bulls						
400	1.4	2.0	11.4	4.2	4.6	5.2	6.2	7.1	10.0
800	1.9	2.2	20.8	7.7	8.3	9.6	11.2	12.9	18.3
1200	...	...	16.2	6.0	6.5	7.5	8.7	10.0	14.3
1600	...	...	19.8	7.3	7.9	9.1	10.7	12.3	17.4
2000	...	...	24.3	9.0	9.7	11.2	13.1	15.1	21.4
2400	...	...	27.9	10.3	11.2	12.8	15.1	17.3	24.6
			Basic intake of nonlactating cows (not including allowance for fetus)						
800	...	...	12.6	4.7	5.0	5.8	6.8	7.8	11.1
1000	...	...	14.4	5.3	5.8	6.6	7.8	8.9	12.7
1200	...	...	16.2	6.0	6.5	7.5	8.7	10.0	14.3
1400	...	...	18.9	7.0	7.6	8.7	10.2	11.7	16.6
1600	...	...	20.7	7.7	8.3	9.5	11.2	12.8	18.2
			Reproduction (add to basic intake during last 2 to 3 months of pregnancy)						
	2.0	2.0	7.2	2.7	2.9	3.3	3.9	4.5	6.3
			Basic intake of lactating cows (not including allowance for production of milk)						
			At 70° and below / At 80° / At 90°						
800	...	...	12.6 / 11.5 / 7.2	4.7	5.0	5.8	6.8	7.1	6.3
1000	...	...	14.4 / 13.1 / 8.2	5.3	5.8	6.6	7.8	8.1	7.2
1200	...	...	16.2 / 14.7 / 9.2	6.0	6.5	7.5	8.7	9.1	8.1
1400	...	...	18.9 / 17.2 / 10.8	7.0	7.6	8.7	10.2	10.7	9.5
1600	...	...	20.7 / 18.8 / 11.8	7.7	8.3	9.5	11.2	11.7	10.4
			Lactation (add to basic intake for each pound of milk)						
			3% fat	0.23	0.24	0.26	0.29	0.32	0.41
			4% fat	0.25	0.26	0.29	0.32	0.35	0.46
			5% fat	0.27	0.29	0.32	0.35	0.39	0.51
			6% fat	0.30	0.31	0.34	0.38	0.43	0.56

TABLE 1. TOTAL DAILY WATER INTAKE [a]

(Part 2—Beef Cattle)

Temperature (Fahrenheit)			40°	50°	60°	70°	80°	90°
Gallons of water per pound of dry matter			0.37	0.40	0.46	0.54	0.62	0.88
Body weight	Expected daily gain	Dry matter daily						
lb.	lb.	lb.	gal.	gal.	gal.	gal.	gal.	gal.
Cattle on maintenance rations [b]								
200	0.0	3.3	1.2	1.3	1.5	1.8	2.0	2.9
400	0.0	5.4	2.0	2.2	2.5	2.9	3.3	4.8
600	0.0	7.2	2.7	2.9	3.3	3.9	4.5	6.3
800	0.0	8.8	3.3	3.5	4.0	4.8	5.5	7.7
1000	0.0	10.4	3.8	4.2	4.8	5.6	6.4	9.2
1200	0.0	11.8	4.4	4.7	5.4	6.4	7.3	10.4
1400	0.0	13.2	4.9	5.3	6.1	7.1	8.2	11.6
1600	0.0	14.5	5.4	5.8	6.7	7.8	9.0	12.8
1800	0.0	15.8	5.8	6.3	7.3	8.5	9.8	13.9
2000	0.0	17.0	6.3	6.8	7.8	9.2	10.5	15.0
Wintering weanling calves								
400	1.0	9.9	3.7	4.0	4.5	5.3	....	....
500	1.0	11.7	4.3	4.7	5.4	6.3	....	....
600	1.0	13.5	5.0	5.4	6.2	7.3	....	....
Wintering yearling cattle								
600	1.0	14.4	5.3	5.8	6.6	7.8	....	....
700	1.0	15.3	5.7	6.1	7.0	8.3	....	....
800	0.7	16.2	6.0	6.5	7.4	8.7	....	....
900	0.5	16.2	6.0	6.5	7.4	8.7	....	....
Wintering pregnant heifers (Weights for beginning winter period; gains average for period)								
700	1.5	18.0	6.7	7.2	8.3	9.7	....	....
800	1.3	18.0	6.7	7.2	8.3	9.7	....	....
900	0.8	16.2	6.0	6.5	7.4	8.7	....	....
1000	0.5	16.2	6.0	6.5	7.4	8.7	....	....
Wintering mature pregnant cows (Weights for beginning winter period; gains average for period)								
800	1.5	19.8	7.3	7.9	9.1	10.7	....	....
900	1.0	18.0	6.7	7.2	8.3	9.7	....	....
1000	0.4	16.2	6.0	6.5	7.4	8.7	....	....
1100	0.2	16.2	6.0	6.5	7.4	8.7	....	....
1200	0.0	16.2	6.0	6.5	7.4	8.7	....	....
Heifers and steers								
400	1.6	10.8	4.0	4.3	5.0	5.8	6.7	9.5
600	1.4	14.4	5.3	5.8	6.6	7.8	8.9	12.7
800	1.2	17.1	6.3	6.8	7.9	9.2	10.6	15.0
1000	1.0	18.9	7.0	7.6	8.7	10.2	11.7	16.6
Bulls								
600	2.3	14.4	5.3	5.8	6.6	7.8	8.9	12.7
800	1.7	15.3	5.7	6.1	7.0	8.3	9.5	13.5
1000	1.6	18.0	6.7	7.2	8.3	9.7	11.2	15.8
1200	1.4	19.8	7.3	7.9	9.1	10.7	12.3	17.4
1400	1.0	21.6	8.0	8.6	9.9	11.7	13.4	19.0
1600	0.0	23.4	8.7	9.4	10.8	12.6	14.5	20.6
1800	0.0	23.4	8.7	9.4	10.8	12.6	14.5	20.6

TABLE 1. *(Continued)*

Temperature (Fahrenheit)			40°	50°	60°	70°	80°	90°
Gallons of water per pound of dry matter			0.37	0.40	0.46	0.54	0.62	0.88
Body weight	Expected daily gain	Dry matter daily						
lb.	lb.	lb.	gal.	gal.	gal.	gal.	gal.	gal.
		Fattening calves finished as short yearlings						
400	2.0	10.8	4.0	4.3	5.0	5.8	6.7	9.5
500	2.0	12.6	4.7	5.0	5.8	6.8	7.8	11.1
600	2.0	14.4	5.3	5.8	6.6	7.8	8.9	12.7
700	2.0	16.2	6.0	6.5	7.4	8.7	10.0	14.3
800	2.0	18.0	6.7	7.2	8.3	9.7	11.2	15.8
900	2.0	18.9	7.0	7.6	8.7	10.2	11.7	16.6
		Fattening yearling cattle						
600	2.2	16.2	6.0	6.5	7.4	8.7	10.0	14.3
700	2.2	18.9	7.0	7.6	8.7	10.2	11.7	16.6
800	2.2	19.8	7.3	7.9	9.1	10.7	12.3	17.4
900	2.2	21.6	8.0	8.6	9.9	11.7	13.4	19.0
1000	2.2	23.4	8.7	9.4	10.8	12.6	14.5	20.6
1100	2.2	24.3	9.0	9.7	11.2	13.1	15.1	21.4
		Fattening two-year-old cattle						
800	2.4	21.6	8.0	8.6	9.9	11.7	13.4	19.0
900	2.4	23.4	8.7	9.4	10.8	12.6	14.5	20.6
1000	2.4	24.3	9.0	9.7	11.2	13.1	15.1	21.4
1100	2.4	26.1	9.7	10.4	12.0	14.1	16.2	23.0
1200	2.4	26.1	9.7	10.4	12.0	14.1	16.2	23.0
		Cows nursing calves, first 3 to 4 months after parturition						
		70° and below / 80° / 90°						
900–1100	0.0	25.0 / 22.8 / 16.8	11.4	12.6	14.5	16.9	17.9	16.2

[a] Total water intake includes both the water drank and that contained by the feed.
[b] Animals that are neither gaining nor losing weight.

mated on the basis of the feed intake of young cattle making no weight gains (Winchester and Hendricks, 1953). Dry matter intake rates of cattle in constant temperature chambers (Ragsdale *et al.*, 1950 and 1951), figure 2, have been used to estimate probable decline in dry matter intake with rising ambient temperature. It is assumed that dry matter intake of nonlactating cattle like that of the Brown Swiss heifers shown in figure 2 does not decline until the ambient temperature exceeds 90° F. A further assumption is that the feed used was exactly 90% dry matter whereas dry matter levels of such feeds only approximate this figure.

Water intake during lactation and the last 2 or 3 months of pregnancy may be thought of as consisting of 2 components, namely one

corresponding to the basic requirement of the animal and another representing an added requirement due to the demands either of pregnancy or of lactation. The water intake rates given by table 1, part 1, are

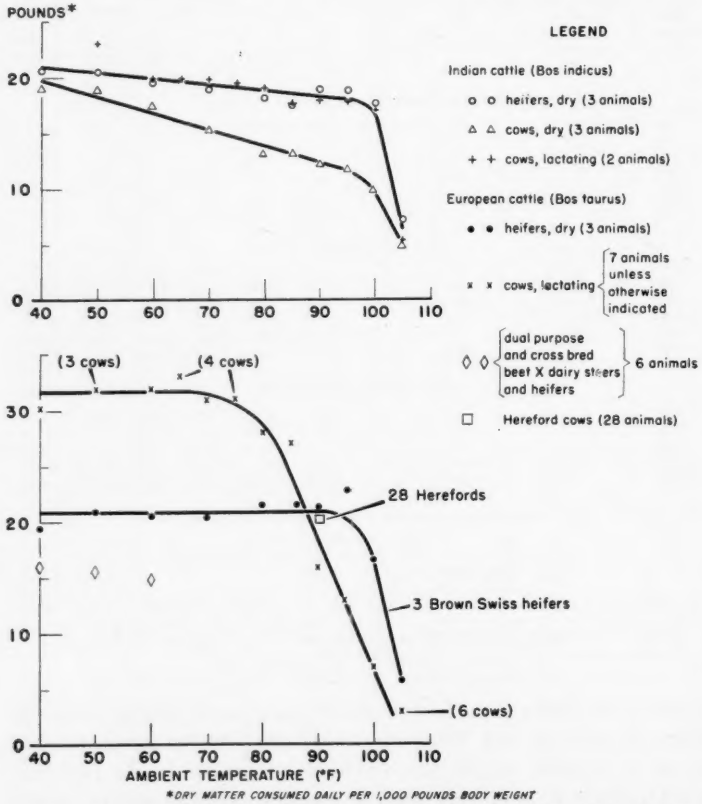
POUNDS*
LEGEND
Indian cattle (Bos indicus)
o o heifers, dry (3 animals)
Δ Δ cows, dry (3 animals)
+ + cows, lactating (2 animals)
European cattle (Bos taurus)
• • heifers, dry (3 animals)
x x cows, lactating
7 animals unless otherwise indicated
◊ ◊ dual purpose and cross bred beef X dairy steers and heifers
6 animals
□ Hereford cows (28 animals)
(3 cows)
(4 cows)
28 Herefords
3 Brown Swiss heifers
(6 cows)
AMBIENT TEMPERATURE (°F)
*DRY MATTER CONSUMED DAILY PER 1,000 POUNDS BODY WEIGHT

Figure 2. Dry matter consumption as a function of ambient temperature. Dry matter intake was assumed to vary with the 0.7 power of body weight. (See Winchester and Hendricks, 1953).

based partly upon dry matter (90% of total feed) given by Loosli *et al.* (1950) table 1, the *basic* water intake levels both of nonlactating and lactating cows given in our table being based partly on the dry matter content of the feed allowance for "maintenance of mature cows". Our basic allowances for pregnant cows differ from those for lactating animals due to the differences between these 2 classes of animals in levels

of feed intake as environmental temperature rises, as shown by figure 2. The decline in feed intake of nonlactating cattle appears to begin only after the temperature reaches 90° while intake of lactating cows begins to decline at about 70° F. Our added allowance for the last 2 to 3 months of pregnancy corresponds to the increase in level of feed intake at that time. Similarly, our allowance for milk production in addition to the basic ration corresponds to Loosli's added feed allowances for milk, plus 0.87 lb. of water for each pound of milk. Water allowances for growing heifers are greater than the basic allowances for cows because they are based on the higher levels of feed allowed the growing animals as compared with the basic allowances of Loosli *et al.* for mature cows.

To obtain an indication as to how closely table 1 may predict water intake levels, estimated levels of intake were compared with actual intake levels of the animals used in this study. These estimated and actual water intake levels are given in table 2. As the table shows, the intake levels of any one of the small groups of animals concerned are seldom predicted exactly by table 1, but the estimated intake levels are quite similar to actual intake except for some of those of the three Brown Swiss heifers. This difference is to be expected in view of the fact that these heifers consumed more water per pound of dry matter at 50° F. and above than did any other animals used in our study. Similarly, because the beef type animals on which information is available at 40° to 60° F. consumed less water per pound of dry matter than the other animals studied, the levels estimated on the basis of the average of the intake data we have used are greater than actual intake of these cattle. It is obvious that even though estimates could be based on the intake level of an extremely large number of animals, the actual intake of individuals or small groups would necessarily be quite different in many cases from the estimates based on average levels.

Dry matter intake rates of beef heifers used in feeding trials in California give some indication of the level of such intake at 90° (Kelly *et al.*, 1955). The heifers weighed around 800 or 900 lb. at the beginning of the trials and gained 0.75 to 1.5 lb. a day for 71 to 84 days. The mean of 20 lb. of dry matter per 1,000 lb. bodyweight per day ingested by these heifers is about what they could be expected to consume under *favorable* temperature conditions (Guilbert *et al.*, 1950), therefore, the fact that they consumed this amount at 90° can be construed to be an indication that dry matter intake at this temperature was not very different from intake at lower temperatures.

TABLE 2. ESTIMATED AND ACTUAL WATER INTAKE [a]

Animals: Kind / Numbers	Lactating cows 7					Brown Swiss heifers 3			Beef cattle 6 at 40° and 50° 4 at 60° 28 at 90°		
				Water intake			Water intake			Water intake	
Ambient temperature	Body weight	Milk daily	Butterfat	Estimate (table 1)	Actual (Ragsdale *et al.*, 1950, 1951)	Body weight	Estimate (table 1)	Actual (Ragsdale *et al.*, 1951)	Body weight	Estimate (table 1)	Actual at 40° to 60° original data, at 90° F. Kelly *et al.*, 1955
° F	lb.	lb.	%	gal.	gal.	lb.	gal.	gal.	lb.	gal.	gal.
40	1168	32.1	4.4	14	17	397	4	4	1010	7	5
50	1192	39.4	4.3	17	20	420	4	5	1100	8	6
60	1192	37.6	4.3	19	21	442	5	6	1030	9	6
70	1195	37.1	4.2	21	22	465	6	8	....	..	..
80	1190	34.3	4.1	21	21	487	7	10	....	..	..
90	1135	25.6	4.2	20	19	521	11	16	872	16	15

[a] Expressed as daily total water intake.

The information presented in figure 1 and table 1 is given in terms of *total water intake* which includes both the water drank and the water contained in the feed. The amount of *free water* that cattle can be expected to drink can be calculated from the information given in table 1 as follows:

$$\text{Free water consumption (gal.)} = \text{total water (gal.)} - \frac{\frac{\%\text{water in feed}}{\%\text{dry matter in feed}} \times \text{daily dry matter intake in pounds}}{\text{weight of water in pounds per gallon}}$$

When the ration consists of hay, grain and similar "dry" feeds that are about 10% moisture, cattle ordinarily obtain only a third of a gallon or less of water a day from the rations. Because this amount is small, in practical situations the difference between *total water intake* and *free water consumption* often can be ignored and the water intake rates given by table 1 used to represent free water consumption. The amount of water a 1,000 lb. animal may be expected to drink compared with estimated total water intake at 70° when growth is normal may be used as an example. Under the section: "Heifers and steers", table 1, part 2, dry matter intake is estimated to be 18.9 lb. and total water intake 10.2 gallons per day. Assuming that the feed is 10% water, we may estimate water consumption (free water drank) as follows:

$$\text{Free water consumption} = 10.2 - \frac{1/9 \ (18.9)}{8.345} \text{ or 10 gallons per day.}$$

In contrast with the small amount of water ingested in hay and grain, the water included in the feed when cattle are on pasture or consuming silage or other succulent feeds may amount to a large part of the animals' water requirement. In order to estimate the animals' need for drinking water while on succulent feeds, the moisture in the feed must be subtracted from the estimated total water intake. An example that illustrates this point is the following: How much water will be drunk by a herd of 100 dairy type heifers of 600 lb. mean body weight allowed 1,000 lb. of alfalfa plus 1,500 lb. of corn silage daily during a month when the mean temperature is 70° F.? If the hay is 10% and the silage 73% moisture (Guilbert *et al.*, 1950), the water in the feed amounts to 1,195 lb. or 143 gallons. The difference between 730 gallons, the estimated intake level given by table 1, and the 143 gallons of water contained by the feed is 587 gallons, the amount that the herd can be expected to drink daily under the conditions described.

Water Intake During Caloric Maintenance Feeding

To obtain an indication as to whether or not the ratio of water to dry matter intake is the same at maintenance as at liberal levels of feed intake, we made use of data reported by Leitch and Thompson (1944) that includes information on 12 steers on submaintenance, 15 on maintenance and 23 on liberal rations. By the method of analysis of variance we found no significant difference between the means of water intake per unit of dry matter ingested at the 3 different nutritional levels; this finding confirms an earlier report of Ritzman and Benedict (1924). The means with their standard errors are 0.38 ± 0.03 on submaintenance, 0.35 ± 0.02 on maintenance, and 0.34 ± 0.01 gallon of water per pound of dry matter on liberal rations.

In view of the fact that the relationship between dry matter and water intake levels, at least for practical purposes, appears to be independent of the level of feed consumption we have based our estimates of water intake of cattle on maintenance rations on the calculated water intake per pound of dry matter and probable dry matter intake of cattle on range forage consumed at a level corresponding to maintenance. Information recorded recently by Bond (1955) makes possible a comparison of estimated water intake of cattle on maintenance rations with the recorded intake of 6 steers fed rations near the level of maintenance in metabolism stalls. The records were obtained during 3 different ten day periods when mean ambient temperature was near 40° F. Mean total water intake of the steers was 0.29 ± 0.02 gallons per pound of dry matter. While this is 22% less than the estimated amount shown by table 1, this much difference is not unexpected in view of the wide differences that exist between intake levels of individuals.

The fact that water requirements can be reduced by a reduction in feed allowances can be put to practical use during brief periods of water shortage. For example, if the regular water supply for cattle in a dry lot were interrupted for several days so that it became necessary to carry the water to them, the amount of water to be transported could be reduced by limitation of feed intake.

Effects of Type of Ration on Water Intake

Protein supplements heavily salted to limit the amounts of the supplement consumed increase water intake from 22% or less (Riggs *et al.*, 1953) to 100% (McIlvain, 1953). Salt added to the ration in an attempt to double the water intake (Kelly *et al.*, 1955) resulted in increases of

TABLE 3. WATER AND DRY MATTER INTAKE OF HEREFORDS AT 90° F.[a]

Year	Days on trial	No. of animals	Ration, type	Body weight[b]	Dry matter[c] daily	Water in feed daily	Water drank daily	Total water intake daily	Temperature of drinking water	Total water (gal.) / Dry matter (lb.)
				lb.	lb.	gal.	gal.	gal.	° F.	
1950	83	4	Hay only	910	21.2	0.3	15.4	15.7	65	0.74
1950	83	4	Hay only	877	20.2	0.3	16.6	16.9	88	0.84
1952	71	10	Hay only	801	18.4	0.2	13.4	13.6	65	0.74
1952	71	10	Hay only	796	17.5	0.2	15.0	15.2	90	0.87
1953	84	7	Hay only	930	19.0	0.3	13.6	13.9	65	0.73
1953	84	6	Hay and grain	965	19.4	0.3	11.3	18.6	65	0.60
1953	84	7	Hay and grain	935	18.1	0.2	13.0	13.2	89	0.73
1954	84	7	Hay and grain	886	15.8	0.2	12.6	12.8	65	0.81
1954	84	7	Hay and grain	878	15.8	0.2	14.1	14.3	83	0.90
mean[d]	..	..	Hay only	865	19.1	0.3	13.8	14.1	65	0.74
mean[d]	..	..	Hay only	819	18.3	0.2	15.5	15.7	89	0.86
mean[d]	..	..	Hay and grain	922	17.5	0.2	12.0	12.2	65	0.70
mean[d]	..	..	Hay and grain	906	17.0	0.2	13.6	13.8	86	0.82
Rations containing large amounts of salt										
1954	84	7	Hay and grain[e]	874	17.0	0.3	20.3	20.6	65	1.21
1954	84	7	Hay and grain	878	16.3	0.3	19.5	19.8	86	1.21

[a] Data are from Kelly et al., 1955.
[b] Mean during trial.
[c] Feed was assumed to be 10% moisture.
[d] Weighted with respect to number of animals.
[e] Pelleted alfalfa hay and barley plus a small amount of oat hay; salt was given in the pelleted feed.

40 to 60% in water consumption (table 3). This table also brings out the interesting fact that while water intake by California Herefords per unit of dry matter was greater when the water was uncooled than when it was cooled so long as ordinary rations were used, when highly salted rations were fed no more water was consumed in relation to dry matter when the water was uncooled than when it was cooled.

Water intake and urine excretion rates are functions of protein intake. Steers on high protein allowances consumed 26% more water than did similar animals on low protein rations (Ritzman and Benedict, 1924). The fact that water intake is related to the protein level of the feed should be kept in mind when protein is supplied in liberal amounts. Whether or not the ratio of water intake to dry matter ingested varies with the ratio between energy and dry matter in a ration apparently is not known. The quality of the rations fed the animals on which our study is based did not influence water intake so far as we can determine. Therefore, even though differences of considerable magnitude existed between rations consumed by the different groups of animals upon which this study is based, in the absence of any reason for not doing so we have "pooled" the data.

The effect of relative humidity on feed and water consumption of cattle was studied by Ragsdale *et al.* (1953). At temperatures below 75° F. the effect of humidity was found to be negligible. The frequency of drinking was greater above than below 75° and at temperatures above 75° water consumption was somewhat less at high than at low levels of relative humidity. This appears to have been a reflection, in part, of lower intake of feed and, in part, of decreased moisture vaporization at high levels of humidity. Some individuals wasted considerable amounts of water at high ambient temperatures when the level of humidity was also high.

Wind up to 9 miles per hour did not influence water intake of dairy animals (Brody *et al.*, 1954). Unfortunately, no information on the effects of wind at velocities above 9 miles per hour on water intake of cattle have come to light.

Water Consumption Patterns

Until the ambient temperature exceeds 80° F., cattle tend to do most of their drinking in the forenoon and late afternoon and evening while very little water is consumed during the night or in the early morning and early afternoon hours. At 90° F., the periods during which no water is consumed tend to be shortened and it appears that the animals then

tend to drink every 2 hours or oftener (Ragsdale *et al.*, 1950, 1951). This behavior suggests that systems that are designed to supply enough water to meet hot weather demands on a continuous flow basis will be ample to meet the peak daily demand at 80° F. and below.

Information on Water Consumption of Range Cattle

Compared with the amount of data available on water intake of cattle under laboratory conditions, information on water consumption of range cattle is extremely scanty. Table 3 gives dry matter and water

TABLE 4. WATER CONSUMED BY DRY RANGE COWS [a]

Temperature, mean, for month	Precipitation month	Month	No. of cows	Body weight mean	Water consumption, daily
° F.	in.			lb.	gal.
42	0.5	Jan.	80	821	3.4
44	1.4	Dec.	80	855	3.1
44	1.6	Feb.	80	647	3.6
45	0.4	Jan.	71	635	3.4
45	0.2	Feb.	79	807	3.4
48	1.2	Mar.	80	714	3.2
48	0.9	Feb.	71	597	3.0
55	0.1	Mar.	71	581	4.0
59	0.3	Apr.	71	662	5.9
68	0.2	May	71	705	7.6

[a] E. B. Stanley (1938) and unpublished data.

intake rates of beef cows at a mean ambient temperature of 90° F. when hay alone, hay and grain, and highly salted rations were fed. Water consumption of a herd of 70 to 80 Hereford cows in Arizona was recorded by Stanley (1938) during a period of over 3 years. A majority of the cows were nursing calves part of the time, but fortunately some data were recorded when the cows were dry; [4] these are given in table 4. No information on feed consumption of these animals is available and therefore a direct comparison with table 1 is impossible. Water consumption from December to March, inclusive, was between 3 and 4 gallons a day, about the amount animals weighing around 700 lb. may be expected to drink on a forage ration but little above the level of maintenance. Table 4 is of possible importance because it shows the quantities of water beef cattle actually drank under a given set of conditions on the range.

[4] Grateful acknowledgement is made of original data on water consumption of range cattle, in greater detail than published information, received from E. B. Stanley.

Discussion

We have used the relationship between water intake and dry matter consumption observed by Ritzman and Benedict (1924), as the basis of our estimates of water intake of beef cattle. The possibility of making such estimates in this way was investigated earlier by Leitch and Thompson (1944) who concluded that such estimates could not be made satisfactorily. To determine how well the data employed by Leitch and Thompson agree with those employed by us, we have calculated the mean and standard error of such of their data as pertain to cattle watered at 8 hour intervals or oftener and presumably kept at temperatures below 70° F. Mean total water intake of 136 individuals per pound of dry matter ingested was found to be 0.45 ± 0.01 gallon; about the same as that of European cattle shown by figure 1 at a temperature roughly midway between 50° and 70° F., the probable range of temperature within which the observations cited by Leitch and Thompson were made. Information on water intake of 4 individuals at 2 different ambient temperatures are included in the data reported by these workers. At 45° intake was 0.49 ± 0.05 and at 77° F. 0.66 ± 0.03 gallon per pound of dry matter; these levels are somewhat higher than those of figure 1 but are in both cases about equally distant from the curve of mean intake of European cattle. With only these limited data at their command, it appears obvious that Leitch and Thompson could not do otherwise than conclude that estimates of water intake could not be based upon dry matter intake of cattle.

The majority of the data on which our estimates are based were recorded when cattle were in chambers maintained at nearly constant temperatures while a minority were obtained under out-of-door temperature conditions. Information recorded under these two very different sets of conditions appear to be in good enough agreement, we believe, to justify the "pooling" of the data as we have done. Herefords at a temperature that fluctuated from 58° to 122°, with a mean of 90°, drank about the same amount of water per unit of dry matter ingested as did cows at a nearly constant temperature of 90°.

The high level of water intake observed at 100° raises a question as to whether or not this apparent intake approximates the water actually drank by the animals or the water ingested plus a large amount of wastage. The report of Ragsdale *et al.* (1951) that at an ambient temperature of around 100° F. and a relative humidity of about 60% the water recovered from the mangers was less than a gallon per day suggests that only a small fraction is wasted, even at high ambient tem-

peratures. On a long term basis, water intake at temperatures above 90° is mainly of academic interest in the U. S. A. for the reason that mean monthly temperatures as high as 100° do not ordinarily occur here (U.S.D.A. Yearbook of Agriculture, 1941).

Summary

Water intake of cattle is a function of dry matter consumption and ambient temperature. When water intake per unit of dry matter ingested was plotted as the ordinate with ambient temperature as the abcissa, curves were formed that remained horizontal between about 10° and 40° F. then rose with rising temperature at an accelerating rate to 100°. Data on European cattle *(Bos taurus)* and Indian cattle *(Bos indicus)* formed separate curves, of which the former is used to estimate water intake of cattle of the familiar breeds. A formula is used to convert water intake of lactating cows to levels comparable to those of dry animals under like conditions of body size, nutrition and air temperature. Positive relationships that have been reported between salt or protein contents of rations are cited to indicate how water intake is influenced by these nutrients. Tables are given showing estimated levels of water intake of cattle, the estimated levels compared with the actual water intake levels used as the basis of this study, and actual intake of a limited number of beef animals under feed-lot and range conditions. Water requirements of cattle in feed lots can be reduced during brief periods of water shortage by a reduction in dry matter intake.

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THE EFFECT OF CERTAIN NUTRITIONAL FACTORS INCLUDING CALCIUM, PHOSPHORUS AND ZINC ON PARAKERATOSIS IN SWINE [1]

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PARAKERATOSIS is a skin disease of swine which has been observed both experimentally and in practical swine husbandry in many parts of the country. Figure 1 illustrates the typical appearance

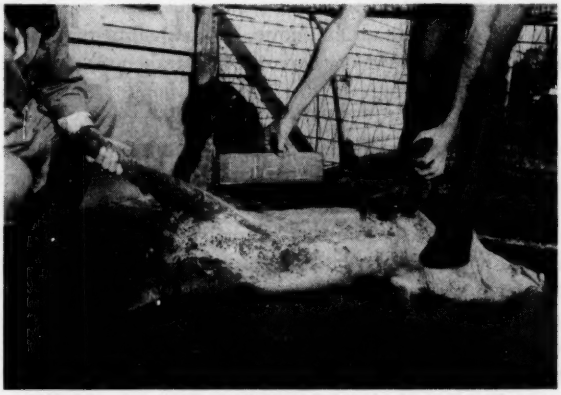

Figure 1. Typical appearance of the legs and ventral body surface of a pig with parakeratosis.

of a pig with parakeratosis. Kernkamp and Ferrin (1953) were the first investigators to describe parakeratosis as a disease entity. They described the symptoms and histopathology of this disease and suggested that it was of nutritional origin. Raper and Curtin (1953) first reported the beneficial effect of feeding zinc to parakeratotic swine. Ellis (1953) reported that the levels of calcium and phosphorus in the ration were associated with a dermatitis observed in pigs receiving a diet containing cottonseed meal. More recently Tucker and Salmon (1955) stressed the detrimental effects of calcium and phosphorus

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and the curative effect of zinc on parakeratotic swine. Hvidsten *et al.* (1955) observed that low levels of the essential fatty acids in the blood of parakeratotic pigs were not associated with the development of parakeratosis.

When parakeratosis first became a problem at the Wisconsin Experiment Station it affected only a small percentage of the pigs on a given experiment but occurred on a variety of rations. While conducting experiments with varying levels of calcium and phosphorus (as bone meal) in swine rations, it was observed that the incidence and severity of parakeratosis became greater as the percentage of bone meal in the ration was increased. Furthermore, early observations suggested that antibiotics and source of protein might influence the behavior of parakeratosis. With these ideas in mind an experiment was designed to test the effect of adding an antibiotic, better quality protein, calcium, phosphorus or zinc on the development of parakeratosis.

Experimental Procedure

Seventy-five normal healthy weanling pigs weighing between 30 and 40 lb. were stratified according to weight and sex and allotted to 10 lots. The pigs were housed indoors and were given 90 I.U. of vitamin D per lb. of ration in the form of irradiated yeast. The pigs in Lot 1 were fed the basal ration which contained 84.5% corn, 11% soybean meal, 3% meat scraps, 1% limestone and 0.5% salt. By analysis, this ration contained 15% protein, 0.82% calcium, 0.47% phosphorus and 35 ppm of zinc. The pigs in the other lots were fed the basal ration plus the following percentages of various supplements replacing an equivalent amount of corn: Lot 2, 2% bone meal; Lot 3, 1.67% limestone (same amount of calcium as Lot 2); Lot 4, 1.33% monosodium phosphate (same amount of phosphorus as Lot 2); Lot 5, 0.75% "Aurofac" (contains 27 mg. of chlortetracycline per lb. of total ration); Lot 6, 0.75% "Aurofac" and 2% bone meal (contains 27 mg. of chlortetracycline per lb. of total ration); Lot 7, 1.7% dicalcium phosphate (same amount of phosphorus as Lots 2 and 4); Lot 8, 50 ppm of zinc added to the ration; and Lot 9, 50 ppm of zinc and 2% bone meal, added to the ration. All of the zinc used in this experiment was in the form of zinc sulfate heptahydrate. Lot 10 was fed the basal ration plus 5% dried skim milk and 3% brewers' yeast in place of an equivalent amount of protein from soybean meal. Each week the pigs were weighed and given arbitrary skin ratings of 0 to 5 depending on the severity of the skin condition. A rating of 0 was given to a pig which showed no skin lesions; a rating of 1 was given to a pig which

had definite skin lesions on the ventral body surface with a slight amount of brown exudate, but the legs were nearly free from excessively keratinized skin; a rating of 3 was given to a pig which had the ventral body surface covered with lesions and exudate and the skin of the legs had accumulated thick keratinized layers in the region of the dew claws, pasterns and hocks; and a rating of 5 was given to a pig which had the entire body surface covered with skin lesions and exudate, with some loss of hair. Ratings of 2 and 4 covered the transition from 1 to 3 and 3 to 5, respectively. The weights and skin ratings were averaged by lots for each week and the data analyzed statistically.

At the end of 12 weeks, when the results of the initial experiment seemed well defined, the pigs in the lots on high calcium (Lots 2, 3, and 7), high phosphorus (Lot 4), antibiotic (Lots 5 and 6) and better quality protein (Lot 10) were stratified according to skin ratings and reallotted into five lots to ascertain the effect of zinc treatment on established cases of parakeratosis. All pigs from these lots exhibited parakeratosis at this time. The pigs were fed the high bone meal ration and were given the following supplements or treatments: Lot 2A (8 pigs), untreated; Lot 2B (8 pigs), 100 ppm of zinc mixed into the ration; Lot 2C (8 pigs), 500 ppm of zinc mixed into the ration; Lot 2D (8 pigs), injected on alternate days with 1 mg. of zinc (as $ZnSO_4 \cdot 7H_2O$) per pound of body weight; and Lot 2E (6 pigs) injected on alternate days with 2 mg. of zinc (as $ZnSO_4 \cdot 7H_2O$) per pound of body weight. Because of local reaction to these injections, the amounts were reduced after five injections to 0.2 mg. and 0.4 mg. of zinc per pound of body weight and were finally stopped entirely at the end of 14 days because of continued local effect of the zinc. The site of injection of the zinc sulfate became walled off by connective tissue, necrotic, and sloughed off. The reactions to the injections seemed not to alter the response of parakeratotic pigs to zinc. Intramuscular and subcutaneous injections were tried, but both caused severe local irritation.

Data on the zinc content of the blood components and the zinc content of various organs from pigs on this experiment will be presented later. (Hoekstra *et al.*, 1956).

Results

Effect of Rations Fed on Development of Parakeratosis

Table 1 shows the effect of the rations fed on the average daily gains and the death rate of pigs at the end of 12 weeks. Three high calcium rations containing 1.4% calcium (Lots 2 and 3) or 1.1%

calcium (Lot 7), with the excess calcium being supplied in the form of bone meal (Lot 2), limestone (Lot 3) or dicalcium phosphate (Lot 7), significantly decreased average daily gains from 0.39 lb. for pigs fed the basal ration to an average of 0.09 lb. for those fed the high calcium rations. The monosodium phosphate supplemented ration had no sig-

TABLE 1. EFFECT OF THE VARIOUS RATIONS FED ON THE AVERAGE DAILY GAINS AND THE DEATH RATE OF THE PIGS

Lot	Ration	Original no. pigs in lot	No. pigs dead 0–12 weeks[b]	Av. daily gain 0–12 weeks on experiment[c]
				lb.
1	Basal[a]	7	1	0.39
2	Basal + 2% steamed bone meal	8	3	0.07
3	Basal + 1.67 % ground limestone	7	5	0.10
4	Basal + 1.33% monosodium phosphate	7	1	0.35
5	Basal + 15 lb. of "Aurofac"[d] per ton	8	1	0.59
6	Basal + 2% steamed bone meal + 15 lb. "Aurofac" per ton	8	1	0.28
7	Basal + 1.7% dicalcium phosphate (18% P)	7	1	0.09
8	Basal + 50 ppm zinc (as $ZnSO_4 \cdot 7H_2O$)	8	0	0.73
9	Basal + 2% steamed bone meal + 50 ppm zinc	8	0	0.89
10	5% dry skim milk + 3% brewers' yeast protein at the expense of S.B.O.M. protein	7	0	0.36

[a] Corn 84.5%, soybean oil meal 11.0%, meat scraps 3.0%, ground limestone 1.0%, salt 0.5%.
[b] Indirectly or directly from parakeratosis.
[c] L.S.D. at $P<0.05=0.29$; and at $P<0.01=0.39$.
[d] Commercial feed supplement of chlortetracycline, containing 3.6 gm. of chlortetracycline per lb., manufactured by Lederle Laboratories Division, American Cyanamid Co., Pearl River, New York.

nificant effect on the average daily gains (0.35 lb. on the high phosphorus ration *vs.* 0.39 lb. on the basal ration). The antibiotic added to the basal or high bone meal rations increased average daily gains by 0.2 lb. per day but these increases were not statistically significant when compared to the basal or high bone meal rations. The addition of 50 ppm of zinc in the form of zinc sulfate to the high bone meal ration or to the basal ration significantly increased average daily gains (from 0.39 on the basal ration to 0.73 on the basal ration+50 ppm of zinc and from 0.07 on the high bone meal ration to 0.89 lb. per day on the high bone meal+50 ppm of zinc). There was no statistical difference in

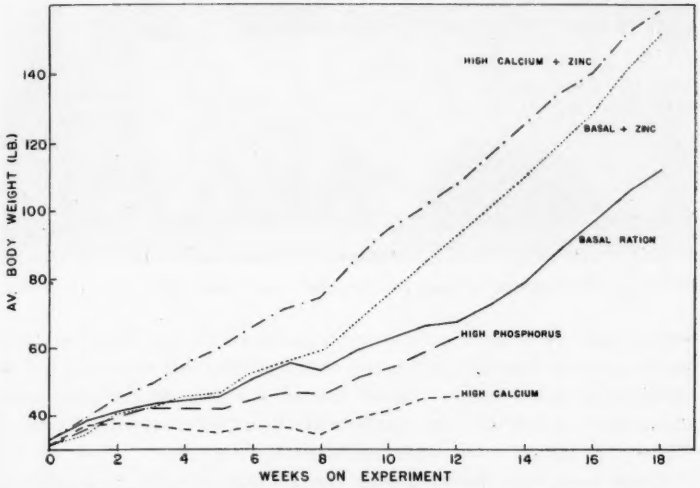

Figure 2. The effects of the addition of calcium, phosphorus or zinc to the basal ration on the growth rate of pigs. High calcium includes lots 2, 3 and 7; high phosphorus, lot 4; basal, lot 1; basal + zinc (50 ppm), lot 8; and high calcium + zinc (50 ppm), lot 9.

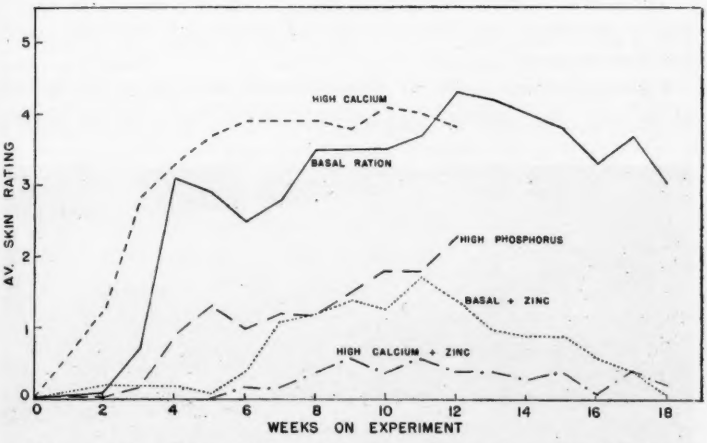

Figure 3. The effects of the addition of calcium, phosphorus or zinc to the basal ration on the skin condition of pigs. High calcium includes lots 2, 3 and 7; high phosphorus, lot 4; basal, lot 1; basal + zinc (50 ppm), lot 8; and high calcium + zinc (50 ppm), lot 9.

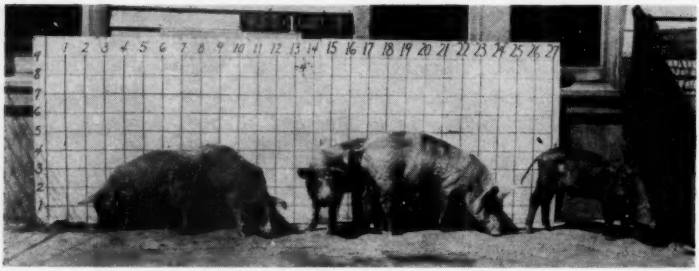

Figure 4. Photograph of pigs fed the high bone meal ration for 12 weeks.

weight gain between the two zinc-supplemented lots. However, the weight gains of the pigs in the zinc supplemented lots were still below standard. It is not known whether the sub-standard weight gains were the result of insufficient zinc supplementation or other unrelated causes. These pigs had no other observable disease symptoms.

There were nine deaths among the 22 pigs fed the high calcium rations; one death among seven pigs fed the basal and monosodium phosphate supplemented rations; and no deaths among the pigs fed the zinc-supplemented rations or the better quality protein ration. When limestone supplied the extra calcium, the death rate was highest.

The growth curves of the pigs fed the high calcium rations, the monosodium phosphate, and zinc-supplemented rations and the basal ration are shown in figure 2.

Figure 3 presents the effects of the various rations on the skin lesions of the pigs. The antibiotic supplemented rations or the better quality

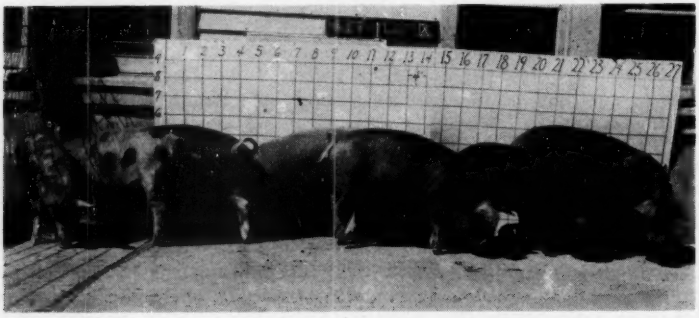

Figure 5. Photograph of pigs fed the high bone meal ration plus 50 ppm of zinc for 12 weeks.

protein ration did not significantly affect the average skin ratings when compared to corresponding control rations. For this reason these rations are not included in figure 3. All the high calcium rations produced the same degree of skin lesions and are therefore summarized together. The high calcium rations hastened the onset of parakeratosis, but had

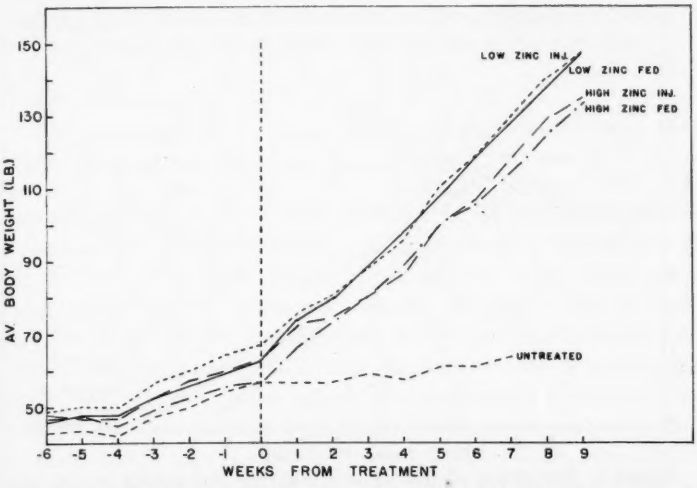

Figure 6. The effects of feeding and injecting zinc sulfate on the weight gains of parakeratotic swine. Untreated received no zinc treatment (lot 2A); low zinc fed received 100 ppm of supplemental zinc (lot 2B); high zinc fed received 500 ppm of supplemental zinc (lot 2C); low zinc injected received a total of 11.2 mg. of zinc per lb. of body weight by injection over a total of 14 days (lot 2D); and high zinc injected received a total of 22.4 mg. of zinc per lb. of body weight by injection over a period of 14 days (lot 2E).

little effect on the skin lesions of pigs still alive after 12 weeks on experiment when compared to the average skin ratings of pigs fed the basal ration. The monosodium phosphate supplemented ration significantly decreased the skin lesions. These data would indicate that calcium aggravates parakeratosis while additional phosphorus to a given level of calcium, if anything, has an alleviating effect on the incidence of the skin lesions. The addition of zinc to the basal or to the high bone meal rations significantly decreased both the extent and degree of the skin lesions. This level of zinc did not prevent the appearance of parakeratosis in all of the experimental pigs. The effect of adding 50 ppm of zinc to the high bone meal ration is illustrated in figures 4 and 5.

Effect of Zinc Treatment on Established Cases of Parakeratosis

The effects of the various zinc treatments on the weight gains of parakeratotic swine are shown in figure 6. The average weight gains of these lots of pigs were plotted for 6 weeks before treatment to show that these pigs were gaining very little before treatment. The addition of 100 or

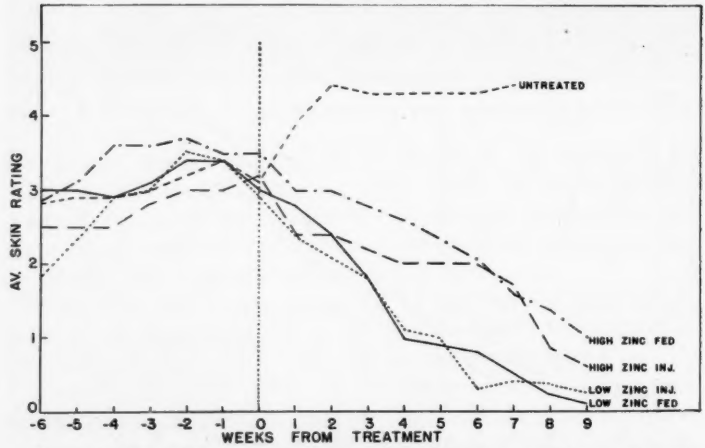

Figure 7. The effects of feeding and injecting zinc sulfate on the skin condition of parakeratotic swine. Untreated received no zinc treatment (lot 2A); low zinc fed received 100 ppm of supplemental zinc (lot 2B); high zinc fed received 500 ppm of supplemental zinc (lot 2C); low zinc injected received a total of 11.2 mg. of zinc per lb. of body weight by injection over a period of 14 days (lot 2D); and high zinc injected received a total of 22.4 mg. of zinc per lb. of body weight by injection over a period of 14 days (lot 2E).

500 ppm of zinc in the form of zinc sulfate to the ration, or the injection of a total of 11.2 mg. and 22.4 mg. of zinc in the form of zinc sulfate per pound of body weight produced dramatic and immediate increases in weight gains. The average daily gains (lb.) for the first 7 weeks of treatment were: Untreated, 0.09; fed low zinc, 1.33; fed high zinc 1.18; injected low zinc, 1.28; and injected high zinc, 1.15. The skin ratings of the pigs given the various zinc treatments are shown in figure 7. The average skin ratings of these lots of pigs were plotted for 6 weeks before treatment to show that these pigs were not recovering from parakeratosis. The severity of the skin lesions of the zinc treated pigs significantly decreased, while the lesions of the untreated pigs

increased. It should be remembered that these pigs were receiving a high bone meal ration. These data indicate that the addition of 500 ppm of zinc to the ration did not elicit a greater response than the addition of 100 ppm of zinc to the ration. In fact there was a greater response to the lower level of zinc in this experiment. Also, the pigs injected with zinc sulfate responded similarly to those fed zinc sulfate, but the injection of zinc cannot be recommended in the prevention or treatment of parakeratosis because of severe local reaction to the injections.

Discussion

The observations of increased incidence of parakeratosis when bone meal, limestone and dicalcium phosphate were fed, and the curative effects of zinc, agree with the work of Tucker and Salmon (1955). The adverse influence of bone meal, limestone or dicalcium phosphate is apparently due to the excess calcium, not phosphorus. Increasing calcium in the form of limestone without simultaneously increasing the phosphorus, increased the death rate. Because the basal ration produced very severe skin lesions it was difficult to evaluate the effect of supplemental calcium on parakeratosis once the syndrome had developed. The mechanism whereby calcium aggravates parakeratosis is unknown, but calcium may be interfering with the absorption or metabolism of zinc.

Parakeratotic pigs injected with zinc ($ZnSO_4 \cdot 7H_2O$) responded in the same way as the pigs fed zinc. This would not necessarily rule out the possibility that zinc is acting in the intestinal tract, since Sheline *et al.* (1943) reported that most of the body zinc whether fed or injected is eliminated via the intestinal tract.

In this experiment the addition of 100 ppm of zinc to the ration cured established cases of parakeratosis, but the addition of 50 ppm of zinc to the ration did not completely prevent the appearance of parakeratosis. This may indicate either that the addition of 50 ppm of zinc to the ration was not sufficient to fulfill the zinc requirement of the pig under these conditions or that possibly zinc is not an absolute preventative or cure for this disease. In subsequent experiments no detectable symptoms of parakeratosis have been observed in pigs receiving 100 ppm of supplemental zinc. The weanling rat's requirement for zinc is about 40 micrograms per day or roughly 4 ppm of zinc in the ration (Hove *et al.*, 1937). In this experiment parakeratosis was observed in pigs consuming a ration containing 90 ppm of zinc (dry basis). Although the beneficial effects of zinc in treating parakeratosis are well established,

this does not necessarily indicate that parakeratosis is an uncomplicated zinc deficiency. If this disease is considered a zinc deficiency, it is difficult to explain the increased incidence of parakeratosis in the last few years.

Summary

The effects of adding an antibiotic, better quality protein, calcium, phosphorus or zinc to rations of pigs on the development of parakeratosis were studied. The basal ration, composed of corn, soybean meal, meat scraps, limestone and salt, contained 15% protein, 0.82% calcium, 0.47% phosphorus and 35 ppm of zinc. The addition of an antibiotic or better quality protein had no significant effect on weight gains or the incidence and severity of parakeratosis. High calcium rations (1.1 or 1.4% calcium) with the additional calcium being supplied by bone meal, limestone or dicalcium phosphate greatly decreased weight gains and increased the onset of parakeratosis when compared to the basal ration. A monosodium phosphate supplemented ration had no significant effect on weight gains but significantly decreased the skin lesions of pigs when compared to pigs fed the basal ration. The addition to the ration of 50 ppm of zinc as zinc sulfate greatly reduced the incidence and severity of parakeratosis but did not completely prevent the appearance of this disease. The addition of 100 ppm of zinc to the ration of pigs with established cases of parakeratosis produced immediate and dramatic responses in weight gains and essentially eliminated the skin lesions within a 9-week period of treatment. The addition of 500 ppm of zinc to the ration did *not* elicit a better response than the 100 ppm level of zinc. Parakeratotic pigs injected with inorganic zinc ($ZnSO_4 \cdot 7H_2O$) responded similarly to those fed zinc, but the injections caused severe local irritation.

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THE RELATIONSHIP OF PARAKERATOSIS, SUPPLEMENTAL CALCIUM AND ZINC TO THE ZINC CONTENT OF CERTAIN BODY COMPONENTS OF SWINE [1]

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A DERMATITIS of swine which Kernkamp and Ferrin (1953) described in detail and designated parakeratosis has been shown to be greatly affected by nutrition. Previous reports have demonstrated that high calcium rations aggravate parakeratosis of swine, while supplemental zinc salts prevent or alleviate this disease (Tucker and Salmon, 1955; Lewis *et al.*, 1955, 1956; Luecke *et al.*, 1955). The addition of zinc sulfate to a swine ration which contained a high level of calcium appeared to overcome the deleterious effects of the excessive calcium on the parakeratosis syndrome (Lewis *et al.*, 1956). The immediate explanation seemed to be that parakeratosis represented a zinc-deficiency disease, and that the requirement of the pig for zinc was dependent on the calcium content of the diet. This is essentially the idea expressed by Tucker and Salmon (1955). The calcium might aggravate the disease by hindering absorption of zinc or by promoting the excretion of zinc, thus depleting the body tissues of their zinc supplies. The purpose of this paper is to present analytical data on the zinc content of the blood components and of certain organs of pigs affected with parakeratosis and data showing the effects of calcium and zinc supplementation on the zinc content of these body constituents. The effects of excess dietary calcium supplied as bone meal and of zinc sulfate on the pH of the contents of the gastrointestinal tract are also considered.

Procedure

The analytical data presented in this paper were obtained from swine on the experiments described by Lewis *et al.* (1956). The lots of pigs from which analytical data were obtained were as follows: lot 1, fed the basal ration; lot 2A, fed a high calcium ration consisting of 2% bone meal added to the basal ration; lot 8, fed the basal ration plus 50 ppm of zinc as zinc sulfate; and lot 9, fed the high bone meal

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ration plus 50 ppm of zinc. Zinc analyses of the blood components from parakeratotic pigs fed or injected with zinc sulfate were also made (lots 2B, 2C, 2D, and 2E).

The method of analysis for zinc was essentially that described by Vallee and Gibson (1948) and Hoch and Vallee (1949). The dry ashing procedure was used throughout for both the blood components and the body organs. Because of the small amount of zinc in some of the swine blood plasma samples, the trichloroacetic acid precipitation method (Hoch and Vallee, 1949), which is limited to the use of 2 ml. of plasma, could not be used. The samples were first dried, then ashed on a hot plate under heat lamps, and finally ashed in a muffle furnace at 550° C. for 12–24 hours. Platinum dishes were used for ashing the samples. If ashing was not complete, the samples were wet with redistilled nitric acid (1:1), dried, and ashed in the muffle furnace for a few hours. Precautions against zinc contamination were taken by acid washing all glassware and platinum dishes and by removing the zinc from all reagents as described by Vallee and Gibson (1948). Zinc was removed from the rinsing water by extracting distilled water with dithizone in carbon tetrachloride. Whenever sufficient zinc was present in the ashed sample, the zinc determinations were made in duplicate. Vallee and Gibson (1948) stated that the limit of error of this method lies within $\pm 5\%$. In our experience, when the sample contained 10 mcg. or more of zinc, the limit of error appeared to be no more than $\pm 5\%$.

Blood samples were obtained as described by Carle and Dewhirst (1942). A saturated solution of sodium citrate which had been freed of zinc by extraction with dithizone in carbon tetrachloride was used as the anticoagulant. The samples were centrifuged at 2500 rpm for 20 minutes, and the plasma removed with a pipette and stored in the frozen state until analyzed for zinc. The red blood cells were washed twice with zinc-free (dithizone extracted) saline, with intermediate centrifugation at 3000 rpm, and finally centrifuged at 3000–3200 rpm for 30 minutes in calibrated centrifuge tubes. The white blood cells were drawn from the surface of red cells between the washings and were discarded. The volumes of the packed erythrocytes were read and the zinc content expressed as mcg. of zinc per ml. of packed erythrocytes. In this study blood plasma samples and red blood cell samples from two pigs of the same treatment group were combined, and zinc was determined on the composite samples.

At slaughter, 19 weeks after the beginning of the experiment, samples of the liver, kidney, spleen, intestine, and pancreas were obtained from

each pig and stored in the frozen state until representative samples were dried, ashed, and the zinc determinations made in duplicate. Only the cortex portion of the kidney was sampled for analysis. The section of intestine was taken about one foot beyond the duodenal loop and was washed free of ingesta. Pancreas samples were freed from connective tissue and fat as much as possible. The zinc contents of the organs were determined both on the fresh frozen weight basis and on the dry weight basis, the samples having been dried at 105° C. for 48 hours.

Since the possibility existed that calcium was aggravating parakeratosis by altering the pH of the gastrointestinal tract and thereby affecting the absorption of zinc, the contents of the stomach, upper small intestine (1–4 feet beyond the duodenal loop), lower small intestine (1–4 feet above the junction with the large intestine) and the large intestine were sampled, and the pH determined with a Beckman model G pH meter. No precautions were taken prior to slaughter to control feed and water intake.

The data were analyzed statistically for differences by the analysis of variance method (Snedecor, 1946).

Results

The effects of the four rations on the zinc content of the blood plasma and erythrocytes of swine are presented in table 1. Relative parakeratosis ratings and average body weights are shown to indicate the extent of the disease in pigs fed the various rations. It should be pointed out that lot 2A represents parakeratotic pigs from lots which for 12 weeks were fed various modifications of the basal ration, none of which contained added zinc, (see Lewis *et al.*, 1956) before they were reallotted and fed the 2% bone meal ration. Close observation of the analytical data indicated that the original ration had no effect on the zinc content of the blood components or organs of these pigs subsequently fed the 2% bone meal ration. In other words, the pigs fed the high calcium rations throughout the experiment did not differ from those fed the high calcium ration only after 12 weeks on experiment in regard to the zinc content of the body components under consideration. However, the depressed growth and the increased severity of the skin lesions noted in the pigs receiving the high bone meal ration after 12 weeks on experiment showed that the presence of excessive calcium in the ration was aggravating the parakeratosis syndrome at the time the zinc analyses were made.

TABLE 1. SUMMARY OF DATA ON THE ZINC CONTENT OF THE MAJOR BLOOD COMPONENTS OF SWINE AS INFLUENCED BY PARAKERATOSIS AND SUPPLEMENTAL BONE MEAL AND ZINC SULFATE

	Weeks on experiment	Basal ration [a]	Basal + 2% bone meal	Basal + 50 ppm zinc	Basal + 2% bone meal + 50 ppm zinc	Least significant difference values	
						$P<0.05$	$P<0.01$
Lot number		1	2 or 2A	8	9		
Relative parakeratosis rating of lot	16	+++	++++	+	trace		
Av. body weight (lb.)	16	97	57	128	140		
Zinc content of erythrocytes (mcg./ml. of packed cells)	12 or 16	7.1±0.3 [b] (3) [c]	7.7±0.5 (3)	6.9±0.2 (4)	8.1±0.7 (5)	No significant difference	
Zinc content of blood plasma (mcg./ml. plasma)	12	0.21±0.03 (3)	0.15±0.04 (3)	0.47±0.04 (3)	0.41±0.03 (3)	0.12	0.19
	16	0.12±0.01 (3)	0.11±0.01 (3)	0.57±0.10 (4)	0.61±0.10 (4)	0.12	0.17

[a] Experiment described by Lewis *et al.* (1956).
[b] Standard error of the mean.
[c] Numbers in parentheses indicate the number of samples analyzed; all samples were composite samples from 2 pigs each.

There were no statistically significant differences in the average concentrations of zinc in the packed erythrocytes of the four lots of pigs. Considerable individual variation was noted. A compilation of all the zinc analyses on erythrocytes, in which no rations or treatments significantly altered the zinc concentrations, showed that the zinc content for growing pigs was 7.4 ± 0.2 (mean $\pm$ S.E.) mcg. of zinc per ml. of packed red cells (27 composite samples from two pigs each). Pigs with severe parakeratosis had as much zinc in the red corpuscles as did healthy pigs. Although excess calcium aggravated the disease and 50 ppm of supplemental zinc greatly reduced the incidence and severity of parakeratosis, neither significantly altered the concentration of zinc in the erythrocytes of the pigs.

Concentrations of zinc in the blood plasma were significantly greater in the lots receiving the 50 ppm of supplemental zinc with or without additional bone meal in the ration. Thus, some of the zinc was absorbed. The lots of pigs which showed severe parakeratosis and which did not receive supplemental zinc exhibited much lower plasma zinc values. Excess dietary bone meal had no significant effect on the plasma zinc concentrations whether or not supplemental zinc was fed. Decreases in plasma zinc values during the period from the 12th to the 16th week on experiment were observed in pigs *not* consuming supplemental zinc while those receiving zinc showed an increase in average plasma zinc during this period. These changes may represent differences in relative feed consumption. The parakeratotic pigs, especially those fed the high calcium ration, were on a very low level of feed intake. Individual variations in plasma zinc concentrations for pigs fed a given ration were rather large, especially when supplemental zinc was fed. There appeared to be no relationship between the plasma zinc level and the severity of parakeratosis within the pigs receiving no supplemental zinc.

Table 2 shows the effects of treating parakeratotic pigs with zinc sulfate, either fed or injected, on the body weight gains, on the skin lesions, and on the zinc content of blood plasma and erythrocytes. All zinc treatments (see Lewis *et al.*, 1956) greatly stimulated body weight gains and markedly reduced the severity of the skin lesions of parakeratosis within 7 weeks following the beginning of treatment. None of the treatments significantly increased the zinc content of the packed red blood cells. It may be important to note that pigs with severe parakeratosis do *not* show an anemia (unpublished data), so there was no change in the relative proportions of red cells and plasma in the treated pigs. Blood plasma concentrations of zinc were increased by all of the zinc treatments. When zinc sulfate was added to the rations, the plasma

TABLE 2. EFFECTS OF TREATING PARAKERATOTIC SWINE WITH ZINC SULFATE ON BODY WEIGHT GAINS, SKIN LESIONS, AND THE ZINC CONTENT OF THE MAJOR BLOOD COMPONENTS

	No. weeks after initiation of treatment	Treatment					Least significant difference values	
			Zinc added to ration		Total zinc injected[e]			
		Untreated	100 ppm	500 ppm	11.2 mg.	22.4 mg.	$P<0.05$	$P<0.01$
Lot number[a]		2A	2B	2C	2D	2E		
Av. daily body weight gain	7	0.09	1.33	1.18	1.28	1.15	0.41	0.55
Av. parakeratosis skin rating[a]	7	4.4	0.5	1.6	0.4	1.7		
Zinc content of erythrocytes (mcg./ml. packed cells)	6[d]	7.7±0.5[b] (3)[c]	7.1±0.5 (3)	7.8±0.1 (3)	7.0±0.2 (3)	6.8±0.1 (3)	No significant difference	
Zinc content of blood plasma (mcg./ml.)	6[d]	0.11±0.01 (3)	0.74±0.08 (3)	1.06±0.11 (3)	0.44±0.05 (3)	0.47±0.05 (3)	0.26	0.39

[a] Experiments described by Lewis *et al.* (1956).
[b] Standard error of mean.
[c] Numbers in parentheses indicate number of samples analyzed; samples were composite samples from two pigs each.
[d] Samples for lot 2A (untreated) were taken four weeks following initiation of treatments.
[e] Per pound of live weight.

zinc values were significantly greater when 500 ppm of zinc were fed than when 100 ppm of zinc were fed. However, the response to treatment was as good or better in parakeratotic pigs fed the lower amount of zinc (Lewis *et al.*, 1956). Plasma zinc concentrations 7 weeks after initiation of treatments did not differ for the lots of pigs injected with the two levels of zinc sulfate. Blood samples from these animals were taken 4 weeks after the zinc sulfate injections were stopped. The zinc

TABLE 3. EFFECTS OF PARAKERATOSIS, SUPPLEMENTAL BONE MEAL AND SUPPLEMENTAL ZINC SULFATE ON THE ZINC CONTENT OF CERTAIN ORGANS OF SWINE

		Basal[a] ration	Basal + 2% bone meal	Basal + 50 ppm zinc	Basal + 2% bone meal + 50 ppm zinc	Least significant difference values	
						P<0.05	P<0.01
Lot number[a]		1	2A	8	9		
No. pigs from which organs were analyzed		6	6	6	6		
Av. parakeratosis skin rating of lot at slaughter[a]		3.3	4.3	0.3	0.3		
Av. body weight at slaughter, lb.		114	67	149	163		
Zinc content (in mcg./gm. dry weight except for pancreas)	liver	95±3[b]	89±5	151±6	138±3	13	18
	kidney (cortex)	102±2	101±3	141±9	117±3	15	20
	spleen	104±1	105±3	107±5	111±4	No significant difference	
	small intestine	101±1	103±3	108±2	104±2	No significant difference	
	pancreas[c]	24±2	23±1	26±1	24±1	No significant difference	

[a] Experiment described by Lewis *et al.* (1956).
[b] Standard error of mean.
[c] Expressed on fresh weight basis.

content of the plasma was still greater than that of the untreated controls. Part of the sustained increase in plasma zinc level may have been due to the greatly increased feed consumption of the treated pigs. The pigs injected with zinc sulfate responded similarly in body weight gains and alleviation of skin defects as those fed zinc sulfate and continued to respond for the 3 week period following the time when blood samples were obtained.

Table 3 presents a summary of the effects of parakeratosis, supplemental bone meal, and supplemental zinc sulfate on the zinc content of certain body organs. Of the organs considered only the livers and the kidneys showed increased concentrations of zinc when the ration

of the pigs was supplemented with 50 ppm of zinc. The differences, although significant, are not exceptionally large. The zinc content of spleen, intestine, and pancreas tissues were remarkably uniform between individual animals and were not significantly altered by parakeratosis, bone meal or zinc. Results for pancreas are expressed on wet weight, because the large variation in the fat and water content of the pancreas

TABLE 4. EFFECTS OF SUPPLEMENTAL BONE MEAL AND SUPPLEMENTAL ZINC SULFATE ON THE pH OF THE CONTENTS OF THE GASTROINTESTINAL TRACT OF SWINE

		Basal[a] ration	Basal + 2% bone meal	Basal + 50 ppm zinc	Basal + 2% bone meal + 50 ppm zinc	Least significant difference values	
						P<0.05	P<0.01
Lot number[a]		1	2A	8	9		
pH of contents of	stomach	2.5±0.2[b] (6)[c]	3.1±0.2 (6)	2.5±0.2 (6)	3.1±0.2 (6)	0.6	0.8
	upper small intestine[d]	5.3±0.2 (6)	5.4±0.1 (6)	5.1±0.1 (6)	5.2±0.2 (6)	No significant difference	
	lower small intestine[e]	6.2±0.2 (5)	6.5±0.1 (4)	6.3±0.1 (6)	6.0±0.1 (5)	0.3	0.4
	large intestine	5.6±0.1 (6)	5.7±0.1 (6)	5.2±0.1 (6)	5.4±0.1 (6)	0.3	0.4

[a] Experiment described by Lewis *et al.* (1956).
[b] Standard error of the mean.
[c] Numbers in parentheses indicate number of pigs.
[d] Sample taken from a segment of the small intestine (ileum) about 1 foot to 4 feet below duodenal loop.
[e] Sample taken from a segment of the small intestine (jejunum) about 1 foot to 4 feet above junction with large intestine.

samples made it difficult to get comparable dry weight measurements. Severity of parakeratosis and rate of gain were *not* correlated with the zinc concentration of any of the organs of pigs receiving *no* supplemental zinc. When 50 ppm of supplemental zinc was fed (lot 8), the addition to the ration of 2% bone meal (lot 9) caused a significant decrease in the zinc content of the liver ($P<0.05$) and of the kidney ($P<0.01$). However, excess bone meal did not significantly reduce liver and kidney zinc levels when *no* additional zinc was fed (compare lots 1 and 2A).

The average pH values of the contents of the gastrointestinal tract for the four lots of pigs are shown in table 4. The stomach was the only part of the tract which showed a consistent and significant change in pH because of the addition of bone meal to the ration. In this case

the addition of 2% bone meal increased the average pH of the stomach contents by 0.6 pH units, which was just significant ($p=0.05$). Further studies have indicated that the pH of stomach contents which are sampled without controlling feed and water intake are subject to great variation. This is not unexpected. In a subsequent experiment with even greater differences in calcium content of the ration no significant effect on the pH of the stomach ingesta of pigs was found. Fifty ppm of zinc as zinc sulfate appeared to slightly, but significantly, lower the pH of the large intestine and possibly that of the lower small intestine in lot 9. These differences in pH are of doubtful physiological significance. Zinc supplements had no effect on the pH of the stomach or the upper small intestine.

Discussion

It has been established that supplemental zinc has a marked preventive or a curative effect on parakeratosis in swine. The data presented indicate that the zinc content of a number of organs in which zinc is known to occur in a functionable form is not significantly altered in pigs with parakeratosis, nor is the zinc concentration increased by administering 50 ppm of supplemental zinc. The zinc present in erythrocytes is believed to be almost entirely in the form of carbonic anhydrase (Hove *et al.*, 1940b; Vallee and Altschule, 1949); thus measurement of the zinc content of red corpuscles is an indirect measure of carbonic anhydrase activity except when very large doses of zinc are administered. From this work it would appear, therefore, that the carbonic anhydrase activity of red blood cells is not decreased in pigs with parakeratosis. Likewise, in experimental zinc deficiency in rats the carbonic anhydrase activity of erythrocytes is not decreased (Hove *et al.*, 1940b; Day and McCollum, 1940).

There are also reports in the literature that zinc is a constituent of, or in some way functions in the action of, phosphatase of the intestine (Hove *et al.*, 1940a) and carboxypeptidase (Vallee and Neurath, 1955) and insulin of the pancreas. In parakeratosis, however, zinc values were not lowered in these organs. Hove *et al.* (1938) observed only a slightly lower zinc content of the bodies of zinc deficient rats (55 mg. of zinc per kg. dry weight) compared to zinc fed controls (70 mg. of zinc per kg.). They reported no difference for the two groups of rats in the zinc concentrations of muscle and skin with hair; slight differences for liver, and more marked differences for small intestine, blood bone and teeth. Marked differences in fecal zinc excretions were noted.

Therefore, the results reported here do not eliminate the possibility that parakeratosis is essentially a zinc deficiency disease. By retarding body growth an animal may be able to maintain the zinc concentrations within rather narrow limits in the organs analyzed while zinc is limiting at some other point. It must also be remembered that total zinc values do not indicate whether the zinc is partly or wholly in a biologically functionable form. The biological aspects of zinc in animals have been reviewed (Hegsted *et al.*, 1945; Vallee and Altschule, 1949). The metabolic patterns, other than CO_2 transport involving carbonic anhydrase, in which zinc may be involved are poorly defined.

Significant increases in the zinc concentrations of the blood plasma, liver, and kidney accompanied the beneficial effects of supplemental zinc on parakeratotic swine. These results may be interpreted in two ways. If it is assumed that there is a shortage of zinc in these tissues in pigs with parakeratosis, the increase with zinc supplementation may represent a return to "normal" concentrations. Literature data which established normal zinc concentrations for the organs and tissues of swine could not be found. Only fragmentary data related to possible zinc toxicity in swine are available. The zinc concentrations in the organs from parakeratotic swine when expressed on wet weight (*i.e.*, in mcg. per gm. fresh weight, liver, 25; kidney, 19; spleen, 25; intestine, 18; and pancreas, 24) fall into the range of normal values reported for other species of animals such as the rat, cat, dog, and man (Hegsted *et al.*, 1945; Vallee and Altschule, 1949). However, as stressed by Vallee and Altschule (1949), there is considerable variation in the literature data which is partly explained by the methods used to determine zinc, many of which are of questionable validity. It is impossible to say whether or not the parakeratotic pigs had normal concentrations of zinc in all the organs considered. The plasma zinc values found for swine in this study are much below those reported for man and certain other species (Vallee and Altschule, 1949; Wolff and Amann, 1951; Berfenstam, 1952). Ten "normal", growing pigs from a herd which showed no parakeratosis and was on pasture had 0.57 ± 0.03 (S.E.) mcg. of zinc per ml. of plasma (five composite samples). This compares with the value obtained for the pigs fed 50 ppm of supplemental zinc in this study. Observations made in subsequent experiments have indicated that the plasma zinc concentration of an individual pig is not a good diagnostic aid for parakeratosis.

If, on the other hand, it is assumed that the zinc concentrations of the plasma, liver, and kidney of the parakeratotic pigs are "normal", the increases may simply represent excess dietary zinc. The work of

Drinker *et al.* (1927) showed that when excessive amounts of zinc were administered to cats, dogs, or rats, the body showed definite increases in the zinc contents of the organs of temporary storage or excretion of zinc such as the liver, bone, and kidney but did not greatly change the zinc content of muscle, spleen, lungs, skin and certain other organs. The zinc concentration of the pancreas increased markedly only when very excessive dosages of zinc were fed. If the tissue increases from the supplementation of 50 ppm of zinc represented zinc entirely in excess of that required by the body, then it would be necessary to explain the alleviating effect of zinc on parakeratosis by some indirect effect. The possible nature of such an indirect effect has not been ellucidated.

The mechanism whereby excess calcium in the diet antagonizes parakeratosis is not yet clear. It appears that the calcium is *not* altering the pH of the intestinal tract and thereby affecting the absorption of zinc. The fact that excess calcium (as bone meal) decreased the zinc content of the liver and kidney, but not of the blood, of pigs fed 50 ppm of additional zinc is significant. There are numerous reports indicating a relationship between calcium and zinc in biology (see Hegsted *et al.*, 1945 for references).

No explanation for the development of the parakeratosis problem in its severe aspects during recent years has been offered. Certainly high calcium rations have been fed, and are being fed, to pigs without causing parakeratosis. Furthermore, it is doubtful that the zinc content of the ingredients of swine rations have changed materially in recent years. The understanding of the manner in which calcium and zinc affect parakeratosis of swine requires further study.

Summary

1. Parakeratosis of swine was antagonized by adding 2% bone meal to a basal ration and was greatly alleviated by the supplementation of the ration with 50 ppm of zinc as zinc sulfate.

2. Zinc supplementation had no effect on the zinc content of packed erythrocytes, spleen, intestine, or pancreas.

3. Adding zinc to the ration increased the zinc concentrations in blood plasma, liver, and kidney.

4. When *no* supplemental zinc was fed, the addition of 2% bone meal to the ration did not significantly alter the zinc content of erythrocytes, blood plasma, liver, kidney, spleen, intestine, or pancreas.

5. When 50 ppm of additional zinc was fed, supplementation of the ration with 2% bone meal decreased the zinc concentrations of liver and kidney, but had no significant effect on the amount of zinc present in erythrocytes, spleen, intestine, or pancreas.

6. The addition of 2% bone meal to the ration had no effect on the pH of the contents of the upper or lower small intestine or the large intestine, but in this experiment appeared to slightly increase the pH of the stomach contents.

7. Zinc supplementation appeared to slightly lower the pH of the contents of the large intestine but had no consistent effect on the pH in the stomach or in the upper or lower portion of the small intestine.

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A STUDY OF THE GROWTH-PROMOTING EFFECTS OF TRIMETHYLALKYLAMMONIUM STEARATE AND ANTIBIOTICS FOR PIGS[1]

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Luecke *et al.* (1952) have reported a growth-promoting effect in swine obtained by the addition of a surfactant (Ethomid C/15) to the ration. Further work by the same investigators was carried out, but the results did not confirm the earlier observations. Beeson *et al.* (1953) were also unable to obtain any growth stimulation form Ethomid C/15, a N-substituted fatty acid amide. However, the same workers reported a significant growth response obtained from the addition of an alkyl benzene sulfonate.

In the case of poultry the results with various surfactants have been extremely variable and in general the results were negative.

Since many quaternary ammonium salts are known to have bacteriostatic properties, it was postulated that perhaps certain of these compounds would stimulate growth. However, it was found in several experiments that positive results were not obtained with a quaternary ammonium salt of the general type corresponding to trimethylalkylammonium chloride (Arquad HT, Armour and Company). Thus, no further consideration was given to this compound in relation to its possible use in swine feeds. However, since Arquad HT is cationic it is chemically possible to combine this compound with a suitable anion. This was done and the resulting compound, trimethylalkylammonium stearate (Armour and Company), was used in a series of experiments to be reported in the present paper. This compound is not soluble in water and is not a surfactant.

Exerimental

The experiments reported in this paper are divided into three separate trials (I, II and III). In each case weanling pigs 6 to 7 weeks of age were used. All animals were sprayed for mange, wormed and vaccinated

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for hog cholera at the start of the trials, and were self-fed the various rations in pens with concrete floors.

The basal rations used in the various experiments are shown in table 1. In each case the protein content of the rations was reduced to 12% when each group attained an average weight of 100 lb.

Statistical treatment of the data was given using the method of Snedecor (1946) for analyzing single classification variance.

TABLE 1. COMPOSITION OF EXPERIMENTAL RATIONS [a]

	Ration	
	Trials I & II	Trial III
	%	%
Corn	78	66
Oats	..	10
Soybean oil meal	14	12
Meat and bone scrap	5	5
Fish meal	..	2
Fish solubles	1	..
Dehydrated alfalfa	..	2.5
Limestone	0.5	0.9
Dicalcium phosphate	0.9	1.0
Iodized salt	0.5	0.5
Trace mineral premix [b]	0.1	0.1
Crude protein content	16.5	17.5

[a] All rations were supplemented with ample amounts of vitamins A and D. In addition all rations were supplemented with a B vitamin supplement (Fortafeed 2–49–90, Lederle) at the rate of 2 lb. per ton.

[b] Calcium Carbonate Corporation.

Results and Discussion

Trial I

The basal ration fed to the pigs in trial I is shown in table 1, and the effects on growth and feed conversion of the various supplements used are shown in table 2. The results indicate that a significant growth response was obtained from the addition of chlortetracycline, and the addition of trimethylalkylammonium stearate at a level of 50 mg. per ton of ration. The lower level of the latter compound produced no significant effect on average daily gain. Feed conversion was apparently not affected by any of the treatments. However, the excellent feed conversions of all lots in this trial (table 2) is certainly an indication of the nutritional adequacy of the basal ration for growth.

TABLE 2. RESULTS OF TRIAL I

(Ten pigs per lot on trial lasting 16 weeks)

Lot No.	Supplement	Av. initial wt.	Av. final wt.	Av. daily gain	Feed per lb. gain
		lb.	lb.	lb.	lb.
1	None	27.0	179.1	1.36(.04)[a]	3.35
2	Chlortetracycline, 10 gm. per ton[b]	27.0	195.6	1.50(.06)*	3.49
3	$(CH_3)_3$ R-stearate, 25 gm. per ton[c]	27.0	182.2	1.39(.02)	3.52
4	$(CH_3)_3$ R-stearate, 50 gm. per ton[c]	26.8	199.2	1.54(.04)**	3.33

* Lot 2 gained significantly faster at the 5% level than lot 1.
** Lot 4 gained significantly faster at the 1% level than lot 1.
[a] Standard error of the mean is given with each average.
[b] Fed as Aurofac, American Cyanamid Co.
[c] Trimethylalkylammonium stearate.

Trial II

A basal ration of the same composition as that fed in trial I was fed to the pigs in trial II (table 1). The results of this experiment are shown in table 3. It can be seen that lots 2 and 3 gained at a significantly greater rate than the control group. It would appear from this trial that a level of trimethylalkylammonium stearate of the order of 200 gm. per ton of feed was ineffective in significantly increasing daily gains (table 4). Furthermore, no positive effect was obtained from the combination of chlortetracycline and trimethylalkylammonium stearate.

Again, as in trial I it can be seen that the feed conversion of all lots in trial II was excellent (table 3).

TABLE 3. RESULTS OF TRIAL II

(Ten pigs per lot on trial lasting 16 weeks)

Lot No.	Supplement	Av. initial wt.	Av. final wt.	Av. daily gain	Feed per lb. gain
		lb.	lb.	lb.	lb.
1	None	22.9	179.5	1.40(.04)[a]	3.38
2	Chlotetracycline, 10 gm. per ton[b]	22.9	192.5	1.51(.04)*	3.26
3	$(CH_3)_3$ R-stearate, 50 gm. per ton[c]	22.8	192.5	1.52(.05)*	3.21
4	$(CH_3)_3$ R-stearate, 100 gm. per ton[c]	22.9	188.7	1.48(.04)	3.22
5	As lots 2+3	22.9	186.0	1.46(.04)	3.25

* Lots 2 and 3 gained significantly faster at the 5% level than lot 1.
[a] Standard error of the mean is given with each average.
[b] Fed as Aurofac, American Cyanamid Co.
[c] Trimethylalkylammonium stearate.

TABLE 4. RESULTS OF TRIAL III
(Eleven pigs per lot on trial lasting 17 weeks)

Lot No.	Supplement	Av. initial wt.	Av. final wt.	Av. daily gain	Feed per lb. gain
		lb.	lb.	lb.	lb.
1	None	29.8	188.5	1.33(.05)[a]	3.74
2	Oxytetracycline, 10 gm. per ton[b]	29.8	190.0	1.35(.04)	3.62
3	$(CH_3)_3$ R-stearate, 100 gm. per ton[c]	30.2	197.0	1.40(.05)	3.70
4	$(CH_3)_3$ R-stearate, 200 gm. per ton[c]	29.9	202.0	1.45(.05)	3.71
5	$(CH_3)_3$ R-stearate, 400 gm. per ton[c]	29.9	191.0	1.35(.04)	3.62

[a] Standard error of the mean is given with each average.
[b] Fed as TM-5, Chas. Pfizer & Co.
[c] Trimethylalkylammonium stearate.

Trial III

In an effort to obtain additional evidence concerning the possible growth-promoting properties of trimethylalkylammonium stearate it was decided to use a practical growing ration. Accordingly, the ration as shown in table 1 was used. The results of this trial are shown in table 4. However, in this trial the addition of trimethylalkylammonium stearate did not significantly increase daily gains at any level tested. No deleterious effect was noted from the addition of this same compound at a level of 400 gm. per ton of feed (lot 5). Moreover, no response was obtained by the addition of the antibiotic at the level used (lot 2).

Feed conversion figures for all lots in trial III indicate a lower feed efficiency than those obtained in the previous two trials.

The reason for the failure to obtain a significantly increased growth response from the antibiotic in the third trial is not known. Certainly, the lack of antibiotic response in this case was not due to disease-free environmental conditions inasmuch as growing pig experiments have been conducted in the same quarters on a virtual year-around basis for the past four years.

The fact that a new environment is not always necessary for the elimination of an antibiotic response has been reported by Waibel *et al.* (1954) for chicks. These investigators reported a disappearance of a growth response to chlortetracycline and penicillin on diets which in previous tests had given positive results.

The results of the three experiments reported in this paper indicate that in two of the three trials the addition of trimethylalkylammonium stearate to the feed significantly increased daily gains. Confirmatory work is definitely needed to ascertain the potential value of this compound as a growth-promotant for pigs.

Summary

In three separate trials involving a total of 145 pigs the addition of trimethylalkylammonium stearate to the ration was found to stimulate growth. However, in only two of the three trials was this growth stimulation found to be statistically significant.

The mechanism by which this compound exerts its effect is unknown at present.

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CHLORTETRACYCLINE SUPPLEMENTS IN SELF-FED RATIONS FOR LAMBS [1]

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IN contrast with the indications of early investigations (Colby *et al.*, 1950a, 1950b), more recent research has suggested that certain of the antibiotics could be included in the rations of fattening lambs with safety and in a number of cases with benefit. Jordan (1952) fed chlortetracycline (Aureomycin) at the levels of 7 to 14 mg. daily to lambs without ill effects, noting that the supplemented lambs were easier to get on full feed. In three experiments, Bridges *et al.* (1953) found that lambs receiving 1.1 to 15 mg. chlortetracycline in crude form (Aurofac 2A) per pound of ration performed as well or better than their controls. An apparent improvement in feed efficiency was evident when the antibiotic was fed at levels of 2.2 to 5.0 mg. per pound of total feed.

Hatfield *et al.* (1954) reported that the addition of 5.5 to 7.6 mg. of chlortetracycline·HCl per pound of the ration of suckling and fattening lambs resulted in small but consistent increases in gain and in improved efficiency of feed utilization. The average performance of suckling lambs fed rations supplemented with crude sources of chlortetracycline (Aurofac), oxytetracycline (TM–5), penicillin (P–2), or a combination of the three antibiotics at levels of about 7.5 mg. antibiotic per pound of ration were slightly better than or equal to the performance of their controls.

Bohman *et al.* (1955) fed chlortetracycline with and without certain added B-vitamins to fattening lambs. These workers reported variable gains, but no adverse or definite beneficial effects could be attributed to the treatments.

Elliott and Ellsworth (1953) suggested that the response to the addition of chlortetracycline to feeder lamb rations may be influenced by the proportion of roughage to the grain that is fed. A consistent increase in gain and improvement in feed efficiency were observed with

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the addition of 10 and 20 mg. of the antibiotic to rations of 80% hay—20% grain, but as the percentage of the grain was increased, the response to the antibiotic became more variable.

Preliminary results in the present study indicated that certain managerial methods as well as diet composition may affect the response of sheep to antibiotic supplementation. In the present investigation, the response to supplementation with chlortetracycline has been studied under a variety of conditions using high-concentrate rations. Emphasis has been placed on the use of self-fed rations and on the effect of higher levels of antibiotic, coupled with the added stress and increased gains resulting from female hormone implantation. Special consideration was given to digestive disorders including enterotoxemia or overeating disease. The incidence of these disorders is generally thought to be greater with the self-feeding regimens.

Experimental

Total mixed rations were used and within each feeding trial, the percentage composition of the basal ration was kept constant throughout the experimental period. The roughages, chopped alfalfa or cottonseed hulls, and the remaining ingredients were mixed mechanically.

Six feeding trials involving 413 lambs were conducted in the fall through early spring feeding periods of the years 1953 to 1955. Fine wool or fine and medium wool crossbred ewe and wether lambs with average weights ranging from 56 to 67 lb. were used. Allotment for the various treatments was made on the basis of weight. The feeding periods ranged from 56 to 84 days with market conditions or the degree of finish of the lambs dictating the time of termination of the experiment.

Except as indicated, chlortetracycline was supplied in a feed grade crude material (Aurofac 2A) containing the equivalent of 3.6 gm. chlortetracycline·HCl per pound of supplement.

When used, synthetic ovarian hormones were implanted subcutaneously in the submaxillary region in the form of 8 pellets containing a total of 10 mg. estradiol and 250 mg. progesterone. In the cottonseed hull rations, a dry stable Vitamin A product was included in the ration to supply a minimum of 3000 I.U. per 100 lb. body weight per day. In all experiments where minerals were not included directly in the mixed rations, free access was allowed to bone meal-salt mixtures.

The general outline of Experiments I to V with the specific levels of chlortetracycline which were used is given in table 1. The complete

percentage compositions of the rations are given in the footnotes to tables 2, 3, and 4.

The lambs in the first trial were hand-fed twice daily. No preliminary adjustment period was used and care was taken to encourage maximum

TABLE I. GENERAL EXPERIMENTAL OUTLINE, EXPERIMENTS I TO V

Experiment and general description of ration	Days on test	Lot No.	Treatment		No. of lambs
			Chlortetracycline, mg./lb. feed	Hormone implant	
I–50% alfalfa,	70	1	0		15
10% cottonseed meal,		2	7.5		13
hand-fed twice daily,		3	15		13
no adjustment period.		4	0		15
		5	7.5		13
		6	15		13
II–50% alfalfa,	56	1	0		12
7.5% cottonseed meal,		2	7.5		12
self-fed.		3	15		12
45% cottonseed hulls,	56	4	0		12
7.5% cottonseed meal,		5	7.5		12
self-fed.		6	15		12
III–50% alfalfa, 7.5% cotton-	70	1	0		28
seed meal, self-fed.		2	15		28
45% cottonseed hulls,	70	3	0		28
7.5% cottonseed meal,		4	15		28
self fed.					
IV–50% alfalfa,	70	1	0	None	21
no cottonseed meal,		2	15	None	20
self-fed.		3	0	Implant, 14th day	21
		4	15	Implant, 14th day	20
V–High concentrate	70	1	0	None	9
(33% alfalfa),		2	15[a]	None	9
self-fed.		3	0	Implant, 1st day	9
		4	15[a]	Implant, 1st day	9

[a] First 28 days only.

feed consumption during the entire feeding period. Self-feeding was used in all remaining experiments. The effects of the increased gains and other added stresses of the ovarian hormone implant (Henneman *et al.*, 1953; Jordan *et al.*, 1955) on the results obtained with antibiotic supplementation were investigated in Experiments IV and V.

Since the carrier of the antibiotic was not necessarily without effect, a sixth experiment was carried out in late summer in which chlortetracycline was supplied as the crude preparation and as the crystalline hydrochloride to determine more clearly the effect of the antibiotic on the pattern of feed consumption. In this study 30 grade fine wool lambs were allotted into six lots of five. Two lots received the basal ration, two the basal ration plus 15 mg. of chlortetracycline in crude form and two the basal ration with 15 mg. of chlortetracycline·HCl mixed in the feed. In view of the susceptibility of hydrochloride to decomposition in water solution, a molasses free basal ration of 50% ground alfalfa, 42.5% ground milo and 7.5% cottonseed meal was used.

All lambs were drenched with phenothiazine prior to the beginning of the feeding trial. The lambs were weighed periodically. In experiments II through V, final weights from which gains were calculated were obtained after the feed had been withheld overnight.

Carcass data were obtained whenever marketing conditions permitted.

Statistical significance of the differences in results were determined from analysis of variance.

Results and Discussion

The results of the three experiments with fattening lambs without hormone treatment are presented in table 2. Data obtained in experi-

TABLE 2. EFFECT OF CHLORTETRACYCLINE IN THE DIET OF FATTENING LAMBS

Experiment and ration	Days on test	Chlortetracycline level	No. of lambs	Death loss	Av. initial weight	Av. daily gain	Av. daily feed intake	Feed per 100 lb. gain
		mg./lb. feed			lb.	lb.	lb./lamb	lb.
I–50% alfalfa [a] (Hand-fed)	56	0	30	1	58.7	0.45	3.34	742
		5	26	0	58.4	0.44	3.15	717
		10	26	0	56.5	0.62	3.78	726
II–50% alfalfa [b] (Self-fed)	56	0	12	4	66.1	0.33	3.47	1037
		7.5	12	0	65.3	0.30	3.35	1126
		15	12	0	65.9	0.34	3.85	1140
45% CSH [c] (Self-fed)	56	0	12	0	64.8	0.30	3.97	1309
		7.5	12	0	65.4	0.32	3.70	1186
		15	12	0	65.6	0.36	4.37	1201
III–50% alfalfa [b] (Self-fed)	70	0	28	0	62.1	0.42	3.29	777
		15	28	0	62.0	0.44	3.26	747
45% CSH [c] (Self-fed)	70	0	28	0	62.1	0.41	3.88	948
		15	28	1	62.1	0.38	3.31	881

[a] Chopped alfalfa—50%, milo—38%, cottonseed meal—10%, bone meal—1.5%, and salt—0.5%.
[b] Ground alfalfa—50%, milo—32.5%, cottonseed meal—7.5%, and molasses—10%.
[c] Cottonseed hulls—45%, milo—37.5%, cottonseed meal—7.5%, and molasses—10%.

ments wherein estradiol-progesterone pellets were implanted are given in table 3.

Rates of Gain

The effects of the antibiotic on the rates of gain have been somewhat variable and inconclusive with the different experiments. In some cases the supplementation of the ration with chlortetracycline appeared to increase gain (Experiments I, II and IV) but the differences in gain were not statistically significant over the 56 to 70-day feeding periods.

TABLE 3. EFFECT OF CHLORTETRACYCLINE IN SELF-FED DIETS OF LAMBS RECEIVING ESTRADIOL-PROGESTERONE IMPLANTS

	Experiment and ration							
	IV–50% alfalfa[a]				V–33% alfalfa[b]			
Hormone implant	0	0	+	+	0	0	+	+
Chlortetracycline, mg./lb. feed	0	15	0	15	0	15[c]	0	15[c]
No. of lambs[d]	21	20	21	20	9	9	9	9
Av. initial wt., lb.	58.6	58.6	58.6	58.6	64.8	64.9	66.6	67.1
Av. daily gain, lb.	0.43	0.46	0.52	0.51	0.37	0.37	0.46	0.53
Av. daily feed intake, lb.	3.00	3.12	3.16	2.91	3.26	3.12	3.21	3.23
Feed per 100 lb. gain, lb.	703	674	614	572	874	849	696	614

[a] Ground alfalfa—50%, milo—40%, and molasses—10%.
[b] Ground alfalfa—33%, milo—55%, molasses—10%, and cottonseed meal—20%.
[c] First 28 days only; no antibiotic used during final 28 days.
[d] Both experiments were 70 days in duration. There were no death losses in any lot.

With the more palatable alfalfa rations, gains were noticebaly higher with the antibiotic fed lambs during the first 28 days of the feeding trials and in Experiment IV the difference in average gain was highly significant statistically ($P<0.01$). In Experiment IV all lots were started with average lamb weights of 59 lb. At 28 days the chlortetracycline-fed lambs which were not receiving the hormone pellet weighed an average of 77 lb., while the unsupplemented lambs, also not implanted, averaged 71 lb. At the end of the 70-day test the difference between the average gains of the lambs was only 2.4 lb. per lamb in favor of the chlortetracycline-fed lambs and was not significant statistically. The extent to which the greater gain of the chlortetracycline-supplemented lambs was due to fill was not determined; however, the average loss in weight following the removal of feed and water for 24 hours at the termination of the feeding trial was equal for both groups (5.4 lb.).

The implantation of the estradiol-progesterone pellets resulted in significant increases in gain (P 0.01) and in a concomitant improvement in efficiency of feed utilization similar to those observed by Henne-

man *et al.* (1953) and Jordan *et al.* (1955). Hyperplasia of the accessory sex organs of wethers resulted from the hormone treatment and, in four of the lambs in Experiment V, this hyperplasia resulted in urethral blockage, difficulty in urination, restlessness, and a marked fluid retention or drainage into the peritoneal cavity, thus offsetting some of the advantages of the increased gain obtained with the hormone treatment.

TABLE 4. AVERAGE WEEKLY FEED CONSUMPTION OF SELF-FED LAMBS SUPPLEMENTED WITH CRUDE AND CRYSTALLINE CHLORTETRACYCLINE

Chlortetracycline supplement	None		Crude 15 mg./lb. feed		Crystalline 15 mg./lb. feed	
Lot No.[a]	1	4	2	5	3	6
Week of experiment	lb./lamb	lb./lamb	lb./lamb	lb./lamb	lb./lamb	lb./lamb
1	17.6	14.4	10.0	12.4	9.8	14.0
2	21.4	16.0	13.2	16.0	19.8	20.2
3	22.2	20.0	21.2	19.6	17.8	20.6
4	18.8	20.6	20.8	20.4	17.2	20.4
5	22.2	21.0	22.4	22.4	21.6	22.0
6	22.8	21.4	22.0	22.2	22.4	22.2
—	—	—	—	—	—	—
12	21.6	25.2	24.4	24.0	22.4	19.2
Total, 12 weeks	251	243	241	240	232	232
Av. initial wt., lb.	66.2	66.2	66.2	66.4	66.4	66.4
Av. daily gain, lb.	0.27	0.31	0.27	0.26	0.28	0.23
Feed efficiency, lb. feed/100 lb. gain	1110	922	1074	1091	1001	1270

Initial average weight of lambs—62 lb. Basal ration: 50% chopped alfalfa, 42.5% ground milo, 7.5% cottonseed meal. Salt and bone meal were fed *ad lib.*

[a] Five lambs per lot.

Efficiency of Feed Utilization

When the current data were combined with those obtained by Bridges *et al.* (1953), for paired comparison, statistical analysis indicated that a significant saving ($P<0.05$) in the average feed requirement per 100 lb. of gain was made by the chlortetracycline-treated lambs as compared with the untreated lambs. In only two cases (Experiment II, table 1, and the summer feeding trial, Experiment VI, table 4), the inclusion of the antibiotic apparently did not improve feed efficiency. However, in trial II, 4 out of 12 control lambs died

during the course of the experiment, thus requiring indirect estimation of the feed consumption by the animals prior to their death and resulting in less reliable feed efficiency data. In Experiment VI, feed consumption was relatively low in both the supplemented and unsupplemented groups and maximum responses were not obtained.

It is of interest to note (table 3) that the improvement in feed efficiency resulting from antibiotic supplementation was evident also when gains were stimulated by treatment with the ovarian hormones. This may suggest the effect of the antibiotic is independent of the metabolic processes of the lambs. It should be noted that the improvement in the efficiency of feed utilization was also evident when the antibiotic was used during the first 28 days only (Experiment V, table 3.

Feed Consumption

Throughout these investigations it was noted that the inclusion of chlortetracycline in the diets of the lambs resulted in a reduction in the feed consumption during the early part of the feeding trial. This general effect of the chlortetracycline on feed consumption is shown in table 4, for Experiment VI. The antibiotic at a level of 15 mg. per lb. of feed, whether supplied as the crystalline hydrochloride or in the crude form (Aurofac 2A), resulted in an initial reduction in the feed consumption during the first week on test, but during the remainder of the feeding trial, the feed intake of the supplemented lambs was equal to that of the control groups. On the other hand there was no evidence of a subsequent stimulation of feed intake as a result of the addition of chlortetracycline to the ration in this experiment. It is evident that the chlortetracycline and not the antibiotic carrier was responsible for a diminution in the amount of feed voluntarily consumed by lambs for a short time after the antibiotic was added to the diet.

In Experiments I and II, the supplementation of the Aurofac 2A providing 10 to 15 mg. of chlortetracycline appeared to stimulate the average feed intake during the entire experimental period. In subsequent experiments, there was no significant stimulation of feed consumption. Since the crude source of chlortetracycline was of a single preparation when used in Experiments I and II and the Aurofac 2A used in the later experiments was obtained from later preparations, as indicated by lot number, it may be that a factor in the chlortetracycline carrier rather than the antibiotic *per se* was responsible. If this is true,

it is significant that the antibiotic did not prevent the expression of the factor stimulating the appetite even at the relatively high level of 15 mg. per lb. of ration.

Digestive Disorders

Although the initial reduction in feed intake by the self-fed lambs may be considered a digestive disorder, it was not accompanied by other visible symptoms in the self-feeding regimens.

In some of the early experiments (Bridges *et al.*, 1953) where hand-feeding was practiced, the inclusion of 5 to 15 mg. of chlortetracycline

TABLE 5. SUMMARY OF DEATH LOSSES OBSERVED IN CONNECTION WITH THE FEEDING OF CHLORTETRACYCLINE OVER A THREE YEAR PERIOD [a]

	No. antibiotic		Chlortetracycline in ration	
	No.	%	No.	%
Total number lambs	230		353	
Deaths from enterotoxemia	10	4.3	0	0
Deaths from all causes	12	5.2	6	1.7

[a] Includes data from Bridges *et al.* (1953).

appeared to cause diarrhea. Whereas initiation of heavy feeding of lambs produced obvious scouring, in the self-feeding regimens the chlortetracycline consistently and markedly reduced scouring. Evidence of diarrhea was noted for as long as ten days in unsupplemented lambs, but in most experiments the chlortetracycline-fed lambs showed softness in the feces for only one or two days. It is evident that chlortetracycline may act as a conditioning factor when used with self-fed rations, but not necesarily so in the hand-feeding regimen.

The cumulative evidence indicates that the antibiotic, chlortetracycline, has suppressed enterotoxemia. Table 5 presents a summary of death losses in lambs in all experiments where this antibiotic was included in the rations of one or more groups of lambs (including the experiments reported by Bridges *et al.*, 1953). The death loss from positively diagnosed enterotoxemia was 4.3% in the unsupplemented lambs. Post mortem examination of the lambs which died while receiving the chlortetracycline did not reveal any evidence that enterotoxemia or overeating disease was the cause of any of these deaths.

Carcass Quality

Official carcass grades (U.S.D.A. Grading Service) were obtained following slaughter of the lambs from all experiments with the exception of the second. There were no consistent differences in carcass grades as a result of the feeding of the antibiotic. The hormone implantation resulted in a slight reduction in average carcass grade to the extent of an average of one-fifth of a grade, but the difference was not significant statistically.

Only limited carcass yield data were obtained. On eight randomly selected lambs from each group in Experiment IV slaughtered in the meats laboratory the average dressing percentages on a chilled carcass, overnight shrink basis, were 54.7% for control lambs, 55.3% for chlortetracycline fed lambs, 54.0% for hormone treated lambs and 53.6% for hormone treated lambs receiving chlortetracycline. The differences were not significant statistically. In Experiment V, average dressing percentages for the control lambs and the chlortetracycline-supplemented lambs without hormone implants were 59.2 and 60.1% on a chilled carcass—overnight shrink basis. Dressing percentages for the lambs implanted with ovarian hormone and receiving no antibiotic and those receiving chlortetracycline were 58.5 and 55.8%, respectively. In Experiment V, the estimation of dressing percentages in the cases of some of the hormone treated lambs was complicated by the blockage of the urethra and extensive fluid retention in the peritoneal cavity. Again the differences were not significant statistically.

Discussion

Perhaps the most significant finding in these experiments is that of the reduction by chlortetracycline supplementation of the incidence of detrimental digestive disorders—diarrhea and enterotoxemia in the self-feeding regimen. Self-feeding has been found to result in lower feed requirements per unit of gain and significantly lower labor costs, but it has not been generally practiced because of a wide-spread fear of excessive death losses. It is believed that the inclusion of such an antibiotic in the self-fed ration results in a safety factor not necessarily eliminating death losses, but reducing them. As yet, it is not known whether the reduction in digestive disorders is the result of controlling the feed intake during the first few days the lamb is in the feed lot or if it is a direct effect of the antibiotic on the microorganisms causing the disorders.

The relatively consistent improvement in feed efficiency upon supple-

mentation with chlortetracycline is somewhat paradoxical. Evans *et al.* (1955) have noted a general trend toward a reduction in the digestibility of roughage in sheep fed chlortetracycline, especially during the early part of the feeding trial. In addition, we are not aware of any data which would indicate an increase in digestibility of any of the nutrients as a result of chlortetracycline in the diet of a ruminant. However, it may be erroneous to assume that maximum efficiency of feed utilization is a necessary attendant circumstance to maximum "digestion" in an animal having a high heat increment such as the ruminant.

With respect to rates of gain, the data are less consistent. Perhaps this is a result of differences in conditions in various experiments. It is significant to note that wherever the rate of gain of the antibiotic supplemented lambs is less that that of the control lambs, the average feed consumption was also lower. This may have been the result of a slower or incomplete recovery from the initial feed reduction caused by the antibiotic under the conditions of the specific test. It seems that more knowledge is needed concerning factors responsible for variations in the overall feed consumption of lambs in a feed lot.

Summary

The inclusion of chlortetracycline in total mixed rations for lambs containing 50 to 67% concentrates hand-fed or self-fed without a preliminary adjustment period resulted in improved efficiency of feed utilization. Implantation of the lambs with pellets containing a total of 10 mg. estradiol and 250 mg. progesterone apparently did not prevent the improvement in feed efficiency.

No statistically significant differences in gain were produced by the antibiotic supplementation. A significant increase in gain and improvement in feed efficiency resulted from the hormone implantation, but these effects were offset to some extent by a slight, but statistically nonsignificant decrease in carcass quality and in dressing percentage and by hyperplastic blockage of the urethra with fluid retention in the peritoneal cavity in some of the wether lambs.

Chlortetracycline apparently reduced the incidence of the digestive disorders, diarrhea accompanying self-feeding and enterotoxemia. This may be the result of a transitory diminution of voluntary food consumption during the first two weeks of the feeding trial.

The addition of chlortetracycline did not produce any marked effects on carcass grade or on the dressing percentage.

It is suggested that an antibiotic may be used effectively as a conditioning factor to reduce the incidence of digestive disorders coincident with placing lambs on a self-fed ration for fattening purposes, and to improve efficiency of feed utilization.

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THE EFFECT OF CHLORTETRACYCLINE ON THE INCIDENCE OF ENTEROTOXEMIA AND WEIGHT GAINS IN LAMBS MAINTAINED UNDER COMMERCIAL FEED-LOT CONDITIONS

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GENERAL improvement in weight gains and feed efficiency, as well as reduced incidence of disease and mortality in some cases, were observed when chlortetracycline [2] was fed at various levels to both suckling and feeder lambs. It has been reported (Bohman *et al.*, 1955; Botkins *et al.*, 1953, 1954; Bridges *et al.*, 1953; Elliott, 1954; Elliott *et al.*, 1955; Gaither *et al.*, 1954; Hatfield *et al.*, 1954; Jordan, 1952; Jordan *et al.*, 1954; Packett *et al.*, 1955) that the continuous feeding of chlortetracycline results in better increases in daily gain and improvement in feed efficiency. However, some workers have obtained inconsistent results or have been unable to show beneficial results with antibiotics in lamb feeding (Colby *et al.*, 1950; Keith *et al.*, 1955; Jordan *et al.*, 1956).

Animals shipped long distances and placed in feed lots may undergo stresses which lower vitality and resistance to disease. The initial adjustment period is one of adaptation to concentrate feed, feed-lot conditions, and potential disease hazards such as enterotoxemia. Considering these stresses, the experiment reported here was conducted to determine the effect of various levels of chlortetracycline in lambs during this adjustment period, as well as continuous feeding during the entire experimental period.

Materials and Methods

Seven hundred and ninety-eight, "old crop", mixed breed, southwestern lambs, averaging 61 lb., were purchased from a midwesten terminal market after shipment from Texas. The lambs were, predominantly,

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[2] Aureomycin is the trade-mark of the American Cyanamid Company for the antibiotic, chlortetracycline.

cutouts and extras from several large shipments, and there was a high percentage of unthrifty animals. They were handled as is customary under commercial conditions, except that no anthelmintic nor prophylactic measures were applied. In the feed lot, the lambs were randomly assigned by groups of ten to eight pens.

The basal ration initially contained 30.5% cracked corn, 26% alfalfa meal, 20.5% alfalfa-molasses meal, and 23% cob meal. Over a period of

TABLE 1. RATION SUPPLEMENTS

Ingredients	Basal	Antibiotic
	lb.	lb.
Dicalcium phosphate	20.0	20.0
Salt	25.0	25.0
Calcium carbonate	25.0	25.0
Trace mineral mix	5.0	5.0
Vitamin A (10,000 units/lb.; dry)	25.0	25.0
Fortafeed [a] 249C feed supplement [b]	6.25	6.25
Alfalfa meal (17%)	795.75	756.75
Soybean meal (Aurofac grade)	16.0	.....
Citrus meal (Aurofac grade)	82.0	.....
Aurofac-10	.....	137.0
	1000.0	1000.0

[a] Reg. U. S. Pat. Off.
[b] Mg. per lb.: Riboflavin, 2,000; Pantothenic acid 4,000; Niacin 9,000; Choline chloride 10,000; Folic acid 60.

ten days, the cracked corn component was gradually increased to 46%, and the cob meal reduced to 7.5%. At the end of ten days, the cob meal was replaced with ground cottonseed hulls.

Chlortetracycline was provided by Aurofac [3]-10 Feed Supplement which contains 10 gm. of chlortetracycline per pound. Two supplements were formulated: a basal supplement, and an antibiotic supplement which was identical, with the exception that it contained 1.25 gm. of chlortetracycline per pound as shown in table 1. Exact amounts of either or both supplements were added to the basal ration to provide a ration to all groups which differed only in the chlortetracycline content.

The eight pens were assigned at random to the experimental groups, two pens per group. All groups were fed for 48 days on a self-feeding basis. The four replicated experimental groups were: Group I—Controls (no chlortetracycline); Group II—25 mg. chlortetracycline per pound of total feed for 21 days, followed by 10 mg. per pound of total feed

[3] Reg. U. S. Pat. Off.

for the balance of the feeding period; Group III—10 mg. chlortetracycline per pound of total feed continuously throughout the feeding period; Group IV—25 mg. chlortetracycline per pound of total feed for 21 days, then no chlortetracycline.

The lambs were weighed at the start of the trial, at 3 days to establish fill, at 21 days, and at 49 days immediately before shipment. Feed consumption, in-transit shrink to market, grades and dressing percentages were recorded. Clinical diagnosis and postmortem examination were made on all sheep becoming ill and/or dying. Bacteriologic examination of tissues was made on a representative number to confirm diagnosis. No attempt was made to interfere with the progress of disease by the application of chemotherapeutic measures.

Results and Discussion

Weights

At the 3-day weighing, all groups were gaining at about the same rate. The sheep gained weight significantly faster ($P<0.01$) during the 0- to 21-day period than in the 21- to 49-day period (table 2).

TABLE 2. THE EFFECT OF CHLORTETRACYCLINE SUPPLEMENTATION ON AVERAGE WEIGHT AND AVERAGE WEIGHT GAIN OF SHEEP

Groups	I	II	III	IV
	Chlortetracycline (mg. per lb. feed)			
First 21 days	0	25	10	25
Next 27 days	0	10	10	0
No. of animals per replicate	99	99	100	100
	100	100	100	100
Av. weight per head, lb.[a]				
Initial	61.0	59.4	62.4	62.4
	60.6	60.7	61.9	61.3
21 days	79.5	79.6	82.5	80.4
	79.4	79.3	81.8	78.6
49 days	91.5	89.8	94.7	90.8
	89.6	91.3	94.9	91.4
Av. daily gain, lb.[a]				
0–21 days	.88	.96	.96	.86
	.89	.89	.95	.82
21–49 days	.43	.37	.44	.37
	.36	.43	.47	.46
0–49 days	.62	.62	.66	.58
	.59	.62	.67	.62

[a] Corrected for lambs that died during the conduct of the experiment.

The principal cause of this difference was believed to be the rapid recovery from shipping shrink. The average final weight and the average daily gain of sheep in Group III, was significantly ($P<0.05$) higher than the average final weight or average daily gain for any other group. In Group III, the average final weight was 4.7% more than the average final weight of the controls, Group I.

TABLE 3. FEED CONSUMPTION AND CONVERSION OF SHEEP

Groups	I	II	III	IV
	Chlortetracycline (mg. per lb. feed)			
First 21 days	0	25	10	25
Next 27 days	0	10	10	0
Av. daily feed consumed, lb.				
0–21 days	4.9	5.0	6.0	4.3
	5.9	4.7	5.0	5.0
21–48 days	5.7	6.1	6.2	6.8
	5.4	6.2	5.3	5.9
0–48 days	5.3	5.7	6.1	5.6
	5.7	5.6	5.2	5.5
Av. lb. feed per lb. gain				
0–21 days	5.49	5.21	6.23	5.02
	6.65	5.34	5.31	6.09
21–48 days	13.39	16.64	14.14	18.26
	14.86	14.43	11.39	12.88
0–48 days	8.57	9.07	9.21	9.67
	9.56	8.89	7.71	8.96

[a] Corrected for lambs that died during the conduct of the experiment.

Feed Consumption and Conversion

During the first 21 days, both average feed consumption and the average amount of feed required to produce a pound of gain were significantly ($P<0.05$) lower than for the 21- to 49-day period (table 3), Again, these differences were strongly influenced by the rapid recovery from shipping shrink.

Mortality

Two animals in the control group died during the first 21 days (table 4) and were asymptomatic. No pathogens were recovered from tissues submitted for bacteriologic examination.

After the 21st day, animals dying showed clinical symptoms usually associated with enterotoxemia, and postmortem findings substantiated

the diagnosis. Bacteriologic examination of representative tissue samples confirmed this diagnosis by isolation of *Clostridium perfringens* Type D, and identification of the toxin. In this period, the control group, which had received no supplement, and Group IV, from which the chlortetracycline supplement had been discontinued, had mortality rates that

TABLE 4. MORTALITY OF SHEEP

Groups	I	II	III	IV
	Chlortetracycline (mg. per lb. feed)			
First 21 days	0	25	10	25
Next 27 days	0	10	10	0
Deaths/Total				
0–21 days	1/99	No		0/100
	1/100	Mortality		0/100
21–49 days	11/98	No		18/100
	1/99	Mortality		12/100
0–49 days	12/99	No		18/100
	2/100	Mortality		12/100

were significantly higher ($P<0.01$), than in the four pens receiving the supplement throughout the trial. It would appear that the mortality rate in the two pens in Group IV was greater than the control pens, but the wide variation between the replicate control pens prohibits such a conclusion, and it is indicated that the death rates of Groups I and IV are not significantly different. This strongly indicates that, under feed-lot conditions, chlortetracycline should be fed continuously during the feeding period.

The patterns of deaths, i.e., relatively high numbers in three of the four pens in which deaths occurred and no deaths in the four continuously supplemented pens suggests the possibility that there may have been some condition existing which would predispose the lambs to enterotoxemia. However, for the purpose of enhancing the conclusion that chlortetracycline effectively controls the disease, there is only one chance in seventy, given four random pens completely free of mortalities, that these four pens would be distributed exclusively among those groups receiving continuous chlortetracyline supplementation.

Carcass Yield and Grading

The average dressed yields of sheep in all experimental groups ranged from 48.6 to 48.9 lb., indicating that yield was not influenced

by supplementation. The distribution by federal grading is summarized in table 5. To obtain a higher percentage of choice carcasses, it would have been necessary to feed the lambs for a longer period. This is indicated from previous experiments (Johnson and Elliott, unpublished data) where the normal "topping off" procedures, as practiced in commercial feeding operations, were followed. However, an impending yearling market warranted their sale at this earlier date. Significantly

TABLE 5. CARCASS GRADES OF SHEEP

Groups	I	II	III	IV
	Chlortetracycline (mg. per lb. feed)			
First 21days	0	25	10	25
Next 27 days	0	10	10	0
Grade				
Choice	68.1%	64.8%	59.5%	50.0%
Good	28.6%	31.0%	35.0%	45.9%
Commercial	2.7%	5.0%	4.5%	2.9%
Culls	0.5%	0.5%	1.0%	0.6%

All carcasses were graded as lambs.

($P<0.05$) fewer carcasses of sheep in Group IV were graded as "choice" than in Groups I and II, the shift being generally to the "good" classification. No other differences could be detected.

Summary

Studies were conducted with 798 lambs to determine the effect of chlortetracycline fed under feed-lot conditions. Lambs were divided randomly into 8 equal lots assigned to 4 feeding groups. The basal ration was fed to Group I. Group II received basal plus chlortetracycline at a level of 25 mg. per pound of feed for 21 days, followed by 10 mg. per pound of feed continuously. Group III received basal plus chlortetracycline at a level of 10 mg. per pound of feed continuously. Group IV received basal plus 25 mg. chlortetracycline per pound of feed for 21 days. The feeding period for all groups was 48 days.

Significantly fewer carcasses of sheep in Group IV were graded "choice" than in Groups I, II and III, the shift being generally to the "good" classification. Under the conditions of this trial, supplementation during the entire feeding period proved to be highly effective in the control of enterotoxemia since no deaths occurred in four pens fed in this manner. In contrast, death did occur in both control pens and

in both pens which had received chlortetracycline for 21 days followed by no antibiotic. All deaths in this latter group occurred after the discontinuance of chlortetracycline supplementation. Average final weights and average daily gains for the group receiving 10 mg. of chlortetracycline per pound of feed continuously throughout the experiment were significantly higher than the controls or other treatment groups.

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DIGESTION COEFFICIENTS AND NITROGEN RETENTION OF YOUNG DAIRY CALVES AS AFFECTED BY ANTIBIOTICS AND ADVANCING AGE

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MOST studies agree in showing that certain antibiotics increase growth rates of calves, but reports of effects on digestibility are conflicting. Bell *et al.* (1951) reported a marked reduction in the digestibility of crude fiber and a somewhat reduced digestibility of dry matter and nitrogen-free extract when 0.2 gm. of chlortetracycline was fed daily to 620 lb. steers. Lassiter *et al.* (1954) substantiated these findings, using yearling steers (650–800 lb.) receiving 0.5 gm. chlortetracycline daily. The dry matter digestion was reduced from 64.0 to 60.5% and the crude fiber from 35.5 to 22.7%. Horn *et al.* (1955) reported that chlortetracycline and penicillin fed to yearling steers reduced the digestibility of protein and crude fiber, chlortetracycline having a greater depressing effect than penicillin. Nitrogen retention was also reduced. Thompson and Grainger (1954) indicated a reduction in crude fiber digestibility and no difference in nitrogen retention from the feeding of chlortetracycline to mature wethers.

In contrast, Murley *et al.* (1952) reported a slightly greater utilization of some feed components (reducing sugars, nitrogen and dry matter) by calves supplemented with chlortetracycline than by non-supplemented calves. Work by Pritchard *et al.* (1955) indicated practically no effect on the digestion of dry matter, ash, protein, nitrogen-free extract or fat by 8-week old calves when chlortetracycline was fed at the rate of 30 mg. per 100 lb. body weight from an early age. Lassiter *et al.* (1955) reported that chlortetracycline had no significant effect on the digestibility of feed nutrients by dairy calves at 5, 8 or 11 weeks. Good comparisons between the relative ages could not be made in their test as some of the components of the diet were changed with age.

Kesler (1954) reported that oxytetracycline included in the milk replacement, or administered by capsule, impaired the *in vitro* breakdown of cellulose by microorganisms of the rumen fluid. Jurtshuk *et al.* (1954) found that the presence of both chlortetracycline and oxytetracycline decreased the ability of rumen bacteria to utilize several carbohydrates (xylose, arabinose, glucose, maltose and cellobiose) *in vitro*.

In studies with fistulated dairy steers, Chance *et al.* (1953) reported that when 0.5 gm. of chlortetracycline was fed, dry matter, crude fiber, crude protein and nitrogen-free extract passed from the rumen at an increased rate.

Experimental Procedure

This study was conducted to determine the effect of the antibiotics, chlortetracycline and bacitracin, and advancing age on nutrient digestibility and nitrogen retention of young dairy calves.

Twelve grade Holstein bull calves approximately 3 days of age were purchased at local auction sales and were allotted randomly to three groups. Group I served as controls, Group II recevied chlortetracycline, and Group III received bacitracin. One calf in Group III developed a navel infection at an early age and was removed from the experiment. The two antibiotics were chosen because chlortetracycline had seemed to be one of the most favorable and bacitracin the least favorable in promoting the growth of dairy calves in experiments conducted at Cornell (Warner *et al.*, 1955; Hogue, 1955).

From the beginning of the experiment, the antibiotics were mixed with the milk or starter once daily at the rate of 40 mg. per 100 lb. body weight per day. The calves were fed about 125 lb. of milk during the first 4 weeks. Thereafter they received good quality mixed birdsfoot trefoil-timothy hay and a commercial calf starter. The hay was chopped into one-inch lengths.

Total urine and feces were collected for 6 days when the calves were 7 weeks and 16 weeks old.

Total intake on a calculated TDN basis was maintained as nearly as possible at 110% of Morrison's (1948) minimum standards for growing dairy cattle calculated to the nearest 10 lb. body weight. Constant feed intakes were generally maintained during a 10-day preliminary period. In an effort to maintain the prescribed level of TDN intake, expected weights of the calves during the collection period were estimated at the beginning of the preliminary period. Five days before the start of the collection period it was obvious that the estimated body weights of three calves (one on each treatment at 16 weeks) were incorrect and increases of from 3 to 4% in feed were made for these animals. Estimated digestible protein intake was about 130% of Morrison's minimum standard at 7 weeks and 180% of that standard at 16 weeks. The hay to grain ratio was maintained at 2:3 throughout both trials. Chemical analyses of feed and fecal samples were conducted for dry matter,

TABLE 1. CHEMICAL ANALYSIS OF THE HAY AND CALF STARTER

Feed	Dry matter	Crude fiber	Crude protein	Ether extract	Ash	Nitrogen-free extract
	%	%	%	%	%	%
Trefoil hay [a]	92.9	27.0	13.8	2.5	4.5	44.7
Calf starter [b]	91.8	7.2	20.8	3.2	6.4	53.9

[a] Hay (sun-cured)—58.7% birdsfoot trefoil and 41.3% timothy.
[b] Calf starter-wheat bran 200 lb., crushed oats 350, cracked corn 355.5, linseed oil meal 200, soybean oil meal 360, alfalfa meal 140, corn distillers solubles 100, dried skim milk 100, irradiated yeast 0.5, cane and corn sugar molasses 160, ground limestone 10, dicalcium phosphate 10, iodized salt 10, and vitamin A feeding oil 4.

crude fiber, nitrogen, ash, and ether extract. Nitrogen determinations were made on the urine samples. All analyses were made according to methods described by A.O.A.C.

Results and Discussion

The chemical analyses of the feeds used are shown in table 1. The effect of antibiotics supplementation and age on the digestion coefficients are reported in table 2.

No effect on the digestibility of any of the feed nutrients except

TABLE 2. EFFECT OF ADVANCING AGE AND ANTIBIOTICS ON DIGESTION COEFFICIENTS OF DAIRY CALVES

Age	No. of observ.	Dry matter	Crude fiber	Crude protein	Ether extract	Nitrogen-free extract
wk.						
			Control			
7	4	71.2	48.1	73.1	64.3	79.8
16	4	72.0	48.8	73.5	63.9	80.3
Av.		71.6	48.4	73.3	64.1	80.0
			Chlortetracycline			
7	4	71.7	46.4	74.9	66.0	80.2
16	4	74.0	47.1	79.0	64.0	81.3
Av.		72.8	46.8	76.9[a]	65.0	80.1
			Bacitracin			
7	3	71.3	47.0	74.1	65.0	79.6
16	3	72.4	47.0	76.2	63.1	80.4
Av.		71.8	47.0	75.2	64.0	80.0
Av. 7	11	71.4	47.2	74.0	65.1	79.8
Av. 16	11	72.8	47.6	76.2[a]	63.7	80.6

[a] Protein digestibility: chlortetracycline > controls, ($P<0.05$) 16 wk. > 7 wk., ($P<0.10$).

TABLE 3. EFFECT OF ADVANCING AGE AND ANTIBIOTICS ON NITROGEN RETENTION OF DAIRY CALVES

Age	No. of observ.	Aver. body wt.	Daily intake (g/100 lb.)			Daily nitrogen retained as	
			Dry matter	TDN	Nitrogen	% of intake	% of absorbed
wk.		lb.					
			Control				
7	4	121	1059	745	32.5	24.4	32.0
16	4	209	1222	870	39.5	30.2	41.0
Av.						27.3	37.0
			Chlortetracycline				
7	4	126	989	698	30.3	33.2	44.3
16	4	230	1203	873	38.8	38.3	48.4
Av.						35.7[a]	46.3[a]
			Bacitracin				
7	3	124	976	684	30.2	27.7	37.4
16	3	218	1216	868	39.6	33.8	44.4
Av.						30.8	40.9
Av. 7	11	124	1007	709	30.6	28.4	38.0
Av. 16	11	219	1214	871	39.3	34.1[a]	44.0[a]

[a] Nitrogen retention: chlortetracycline > controls, ($P<0.05$); 16 wk. > 7 wk., ($P<0.05$).

protein was detected statistically by analysis of various (Snedecor, 1946) and Duncan's multiple range test (Duncan, 1955). The apparent digestibility of protein was higher for the chlortetracycline supplemented group than the control group ($P<0.05$). The average protein digestibility was higher for the bacitracin group than the controls, but the difference was not statistically significant. The calves also digested more protein at 16 weeks than at 7 weeks ($P<0.10$).

The digestibility of all nutrients was relatively high even at 7 weeks of age, being 71.4 and 47.2% for dry matter and crude fiber, respectively. The value for crude fiber digestibility compared favorably with the 45.2 and 46.0% digestibility reported by Lassiter *et al.* (1955) for 8- and 11-week old calves.

The data relative to nitrogen retention are given in table 3. In order

TABLE 4. GROWTH DATA OF THE CALVES

Treatment	No. of calves	Gain, to 6 wk.		Gain, 6 to 16 wk.	
		Total	Daily	Total	Daily
		lb.	lb.	lb.	lb.
Control	4	25.8	.66	85.3	1.29
Chlortetracycline	4	29.0	.74	104.5[a]	1.58
Bactracin	3	28.0	.72	94.0	1.42

[a] Significantly greater than control ($P<0.05$).

to evaluate more critically the factors relating to the nitrogen retained, average body weights as well as dry matter, TDN and nitrogen intakes during the collection periods have been shown. The effect of antibiotics and age on nitrogen retention was similar to the effect on apparent digestibility of protein. The chlortetracycline-fed calves retained a greater proportion of the dietary and absorbed nitrogen than the control calves ($P<0.05$). Also the bacitracin-supplemented calves retained more nitrogen as an average than the controls, but the difference was not statistically significant. Calves retained a greater proportion of their dietary and absorbed nitrogen at 16 weeks than at 7 weeks of age ($P<0.05$).

These data clearly indicate that under the conditions of these experiments older calves as well as those receiving chlortetracycline digested more dietary protein and used the absorbed nitrogen more efficiently. This latter aspect is even more interesting in light of the extremely high level of dietary protein that was fed. Since the primary objective of this study was to ascertain the utilization of a standard ration fed under similar conditions, the hay to concentrate ratio was held constant and the level of TDN intake was adjusted to changes in body weight. As a consequence, the protein intake became a function of these two factors. Because of the high protein content of the dry calf-starter, the nitrogen intakes were considerably above those recommended by Morrison (1948). It will be noted that the TDN intake per unit of weight was not the same for the two age groups. This variation is in accordance with the recommended allowances prescribed by Morrison (1948) for these weights. While the difference in energy intake could have influenced the nitrogen retained, (Lofgreen *et al.*, 1951) the nitrogen to TDN ratio was essentially the same for both weight groups.

It seems reasonable to suggest that the improved nitrogen utilization may be a result of changes in rumen function affecting protein degradation and synthesis.

Summary

Eleven Holstein bull calves were used to study the effect of the antibiotics, chlortetracycline and bacitracin, and of advancing age on the digestibility of feed and the nitrogen retention of dairy calves. Four calves were used as controls, four received chlortetracycline and three received bacitracin. Both antibiotics were fed orally at the rate of 40 mg. per 100 lb. body weight per day from 3 days of age throughout the experiment. Fecal and urinary collections were made when the

calves were 7 and 16 weeks old. There was no effect on the digestibility of dry matter, ether extract, crude fiber or nitrogen-free extract. Chlortetracycline increased both the apparent protein digestibility and nitrogen retention ($P<0.05$). At 16 weeks as compared with 7 weeks apparent protein digestibility ($P<0.10$) and nitrogen retention ($P<0.05$) were also increased.

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THE EFFECT OF ORGANIC ARSENICALS, CHLORTETRACYCLINE AND LINSEED OIL MEAL ON SELENIUM POISONING IN SWINE

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TWO organic arsenicals, arsanilic acid and 3-nitro-4-hydroxyphenylarsonic acid, have been found to give protection against selenium poisoning in swine (Wahlstrom *et al.*, 1955) and in rats (Hendrick *et al.*, 1953).

Moxon (1941) presented evidence that linseed oil meal when incorporated into the ration at a level of 25% protected rats and dogs against selenium poisoning. Olson and Halverson (1954) and Olson and Palmer (1955), working with rats, reported that 20% of linseed oil meal gave good protection against 10 p.p.m. of selenite selenium while levels of 5 and 10% did not. When linseed oil meal and organic arsenicals were fed together there was an indication that the protective effects were additive; however, these workers were unable to demonstrate this conclusively.

The objectives of the studies reported here were to determine whether linseed oil meal would add to the protective effect of the organic arsenicals in counteracting selenium toxicity in swine. In addition, these studies were designed to determine the effect of chlortetracycline, alone or in combination with arsanilic acid, as a preventive against selenium poisoning in swine.

Experimental Procedure

This study consisted of two experiments conducted with weanling pigs in concrete drylot. Experiment I consisted of six replicated lots of four pigs each. One replicate was started one week earlier than the other in order to obtain similar initial weights between replicates. The pigs were allotted into groups of four on the basis of breed, litter and weight, and allotted at random to the various treatments.

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[2] Grateful acknowledgement is made to Abbott Laboratories, North Chicago, Illinois, for funds and arsanilic aicd; to Dr. Salsbury's Laboratories for the 3-nitro-4-hydroxyphenylarsonic acid; to American Cyanamid Co., Pearl River, N. Y. for chlortetracycline; and, to Merck & Co., Rahway, N. J. for the B-vitamins.

TABLE 1. COMPOSITION OF RATIONS FED

Ration designation	Experiment 1		Experiment 2
	A	B	C
Ground yellow corn	79.7	79.7	82.0
Soybean oil meal	14.0	....	11.2
Linseed oil meal	....	14.0	....
Tankage	5.0	5.0	5.6
Steamed bone meal	0.8	0.8	0.7
Trace mineral salt	0.5	0.5	0.5
Vitamin supplement [a]	+	+	+
Sodium selenite [b]	+	+	....

[a] Vitamin supplement mixture provided the following additions to each pound of ration: 6 mg. niacin, 5 mg. pantothenic acid, 1 mg. riboflavin, 125 mg. choline chloride, 4 mcg. B_{12}, 1000 USP units vitamin A and 125 USP units vitamin D.
[b] Added to supply 13 p.p.m. of selenium to the total ration.

In Experiment II, 40 purebred Duroc pigs were used. The pigs were grouped into five outcome groups. Where outcome groups could not be made up of litter mates, other comparable pigs were selected. Within the outcome groups, the pigs were assigned to the experimental treatments at random.

The composition of the experimental rations is presented in table 1. Arsanilic acid was incorporated in the ration at a level of 0.01% and 3-nitro-4-hydroxyphenylarsonic acid at a 0.005% level. Chlortetracycline was used at a level of 10 gm. per ton. The treatments are described in tables 2 and 3.

TABLE 2. EFFECT OF ORGANIC ARSENICALS AND LINSEED OIL MEAL IN COUNTERACTING SELENIUM POISONING IN PIGS

Ration	A	B	A[a]	B[a]	A[b]	B[b]
Lot number	1	2	3	4	5	6
No. of pigs started [c]	8	8	8	8	8	8
No. of pigs finished	8	8	6	8	7	8
Av. initial wt., lb.	29.1	29.0	28.9	29.0	29.0	29.0
Av. final wt., lb.	112.1	112.0	134.3[d]	131.8	132.1[d]	128.8
Av. daily gain, lb.	0.99	0.99	1.25[d]	1.22	1.24[d]	1.19
Av. daily feed, lb.	3.32	3.97	3.06	4.18	3.48	4.12
Feed/cwt. gain, lb.	344	403	300	344	298	347
No. of pigs showing Se toxicity symptoms	4	1	3	0	2	0

[a] Plus 3-nitro-4-hydroxyphenylarsonic acid.
[b] Plus arsanilic acid.
[c] Two replicates of four pigs each.
[d] Data for pigs that finished the experiment.

TABLE 3. EFFECT OF ARSANILIC ACID AND AUREOMYCIN IN COUNTERACTING SELENIUM POISONING IN SWINE

Additions to ration C	None	Se[a]	Se + Arsanilic Acid	Se + chlortetracycline	Se+ Arsanilic Acid+ chlortetracycline
Lot number	1	2	3	4	5
No. of pigs started	8	8	8	8	8
No. of pigs finished	8	8	8	5	8
Av. initial wt., lb.	26.4	26.2	26.1	26.4	26.4
Av. final wt., lb.	156.2	137.2	154.8	166.2[b]	170.5
Av. daily gain, lb.	1.33	1.13	1.31	1.45[b]	1.48
Av. daily feed, lb.	4.39	3.49	4.26	4.07	4.90
Feed/cwt. gain, lb.	330	308	324	328	333
No. of pigs showing toxicity symptoms	0	2	0	4	0

[a] Sodium selenite added at a level of 10 p.p.m. of selenium to rations fed lots 2, 3, 4 and 5.
[b] Data for pigs that finished the experiment.

Results and Discussion

The results of Experiment I are presented in table 2. The effectiveness of the two arsenicals in protecting against selenium toxicity is shown in the growth response of Lots 3, 4, 5 and 6 compared to Lots 1 and 2. The average daily gain of Lot 3 is somewhat out of proportion however, since it was necessary to remove two of the severely affected pigs from this lot and the data of these pigs are not included in table 2. The one pig which was removed from Lot 5 died of unknown causes.

Arsanilic acid appeared to give better protection than 3-nitro-4-hydroxyphenylarsonic acid when fed with soybean meal since in Lot 5 the two affected pigs showed very mild selenium symptoms while in Lot 3 the three affected pigs all exhibited quite severe symptoms. Likewise, three of the four selenized pigs in Lot 1 exhibited very severe symptoms. These symptoms included emaciation, loss of hair, hoofs on all feet separated from the coronary bands by about one-half inch, and cirrhosis and atrophy of the liver.

The toxicity of the seleniferous diets was reduced by replacing soybean oil meal with linseed meal. It will be noted from table 2 that only one of the pigs receiving ration B, which contained 14% linseed oil meal, showed the typical selenium poisoning symptoms. On the other hand nine of the pigs receiving ration A showed some toxicity symptoms. This protective effect was not apparent in the growth rate of the pigs, as all corresponding lots (Lots 1 and 2, 3 and 4, or 5 and 6) of pigs

grew at approximately the same rate. The pigs consumed more of the linseed meal ration than the soybean meal ration but the former ration was much less efficient. Approximately 50 lb. more feed were required per hundredweight of gain with ration A than with ration B. This is in agreement with earlier work which indicated linseed oil meal was not an efficient protein supplement for swine when it constituted the major portion of the protein supplement (Robison, 1921; Snyder, 1930; Weber *et al.*, 1928).

A summary of the results of Experiment II are presented in table 3. That arsanilic acid was effective in preventing selenium toxicity symptoms is indicated in a comparison of the daily gains of Lots 1, 2 and 3. Adding selenium to the basal ration decreased the rate of gain from 1.33 to 1.13 lb. per day. The addition of arsanilic acid to the ration containing selenium restored the rate of gain to that of the controls. Further evidence of the protective effect of arsanilic acid is that none of the pigs in Lots 3 or 5 showed any visible signs of selenium toxicity.

Chlortetracycline did not appear to have any effect on counteracting the selenium toxicity. Two of the pigs in Lot 4, which received chlortetracycline, developed severe selenium symptoms and were removed from the experiment. One other pig in this lot died from unknown causes. Although the antibiotic did not protect against the selenium poisoning it produced a growth response in those pigs which were not affected by the selenium. This is particularly true in Lot 5 which received the combination of arsanilic acid and chlortetracycline. It is believed that the arsanilic acid protected against the selenium and that the antibiotic caused the growth response. This would appear to be the case since the growth rate of the pigs receiving the selenium ration with arsanilic acid was equal to the rate of gain of the control lot whereas the pigs receiving the selenium ration plus arsanilic acid and chlortetracycline gained at an average rate approximately 10% greater than the controls. Slight, but statistically insignificant, increases in rate of gain have been reported when arsanilic acid is added to non-seleniferous rations fed to healthy pigs (Hanson *et al.*, 1955; Wahlstrom *et al.*, 1955).

An attempt was made to determine whether the severely selenized pigs would grow at a normal rate if they were removed from the selenium ration and fed a well-balanced ration. The two selenized pigs from Lot 4 were removed after 7 weeks on the experiment. At this time they averaged 26.5 lb. in weight and exhibited all of the external symptoms of selenium toxicity as described previously. The growth re-

sponse of these two pigs was immediate and their average gain was 1.86 lb per day up to a weight of 205 lb. One of the pigs remained sore and tender footed throughout the trial although the cracked hoofs healed. The pigs were slaughtered at market weight and the internal organs examined for selenium damage. The only organs appearing abnormal after 14 weeks on a non-seleniferous ration were the livers, which were hobnailed and had large areas of cirrhosis. The short period of 7 weeks had apparently caused permanent damage to this organ. The selenium content of the livers was quite low (0.40 p.p.m.). Moxon (1941) reported levels of 6.4 and 9.5 p.p.m. of selenium in the livers of pigs slaughtered after 20 weeks on a seleniferous ration.

Summary

Two experiments involving a total of 88 pigs were conducted to determine the effectiveness of organic arsenicals, linseed oil meal and chlortetracycline in counteracting the effects of chronic selenium poisoning in pigs. Arsanilic acid at a level of 0.01% gave good protection against up to 13 p.p.m. of selenite selenium while 3-nitro-4-hydroxyphenylarsonic acid (.005%) gave its best protection when used in combination with linseed oil meal.

In one experiment linseed oil meal protected against the visible signs of selenium toxicity but did not alter the rate of gain of pigs fed selenized rations. This protection was evidenced whether the linseed oil meal was fed alone or in combination with either of the organic arsenicals, although the combination of linseed oil meal and organic arsenical gave the best protection.

In a second experiment chlortetracycline did not protect against selenium poisoning but it did increase the growth rate of those pigs fed a combination of arsanilic acid and chlortetracycline.

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EXPERIMENTALLY PRODUCED URINARY CALCULI IN SHEEP[1]

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THE formation of calculi in the urinary tract of animals, including man, has been studied for many years. Many factors have been implicated in the etiology of the formation of urinary liths, but there are few critical data supporting any one of these.

A number of minerals have been associated with the formation of urinary calculi. Cunningham and Cunningham (1938) reported that calculi were formed in rats when a high serum calcium level was associated with a low serum magnesium. On the other hand, Eveleth and Millen (1939) reported a large number of calculi cases in sheep fed a dry lot ration reportedly low in calcium and high in magnesium. A low calcium level in the diet was also implicated by Haag and Palmer (1928).

A high phosphorus diet has been reported as predisposing to the formation of calculi in sheep and rats (Bell and Kick, 1935; Haag and Palmer, 1928; Lindley *et al.*, 1953; and Taysom *et al.*, 1953). Lindley *etal.* (1953) and Taysom *et al.* (1953) observed a high incidence of calculi in sheep receiving a phosphorus supplement in the form of 11 grams of potassium acid phosphate (K_2HPO_4) per pound of feed.

Taysom *et al.* (1953) reported that a diet consisting of either 25 or 40% molasses dried beet pulp was conducive to urinary calculi formation in sheep. Others have also associated the feeding of molasses with calculi formation (Evvard *et al.*, 1923).

The present study was undertaken to determine if the high incidence of calculi from including molasses dried beet pulp in the diet of wether lambs is due to the molasses or the beet pulp, and further, to determine if the potassium or the phosphorus in potassium acid phosphate fed at the rate of 11 gm. per pound of feed is responsible for the increased incidence of calculi.

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TABLE 1. COMPOSITION OF DIETS, BY LOT [a]

Lot	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Wheat straw, %	46	46	46	46	37	38	39	40	24	24	24	24	15	15	15	15
Beet pulp, % (without molasses)	..	..	..	..	..	..	..	..	24	24	24	24	25	25	25	25
Beet molasses, %	..	..	..	..	16	14	12	9	..	..	..	..	9	9	10	10
Cane sugar, %	4	4	4	4	..	..	..	..	4	4	4	4	..	..	..	..
Wheat, %	15	15	15	15	14	14	15	15	14	14	14	14	15	15	15	15
Oats, %	17	17	17	17	16	16	17	17	16	16	16	16	17	17	17	17
Linseed meal, %	18	18	18	18	17	18	17	19	18	18	18	18	19	19	18	18
K_2HPO_4 lb./ton	48	..	..	..	48	..	..	..	48	..	..	..	48	..	..	..
H_3PO_4 lb./ton	..	27	..	27	..	27	..	27	..	27	..	27	..	27	..	27
K_2CO_3 lb./ton	..	..	38	38	..	..	38	38	..	..	38	38	..	..	38	38
Vit. A, gm/ton (10,000 I.U./gm.)	68.0	68.0	68.0	68.0	63.0	64.9	67.0	69.0	65.4	65.4	65.4	65.4	69.0	69.0	68.0	68.0

[a] Five sheep per lot.

Experimental Procedure

Eighty crossbred white-faced wether lambs, averaging 76 lb. when purchased, were fed a mixed grass-alfalfa hay diet during a pre-experimental period of 100 days. The hay was fed twice daily and salt and water were supplied *ad libitum* during this time.

The animals were then divided into 16 lots of five sheep each and assigned at random to the experimental diets (table 1). The average weight was 98 lb. The concentrate and roughage portion of each diet was mixed and pelleted. Twice daily the wethers were group-fed all they would consume of the pellets. All of the diets were supplemented with an adequate amount of vitamin A to eliminate the possible influence of low vitamin A intake on the occurrence of calculi. Water and salt were always available.

A 24-hour urine sample was collected from each animal once each month for the first three months of the experimental period. The collections were made by placing the animal in a metabolism cage for 24 hours. While in the cage, the lamb was fed the average amount of feed consumed by each sheep in the lot from which he came. Water was available at all times. The urine and feces voided were directed into separate collecting pans by a metal shelf under the cage. The feces were discarded. The 24-hour urine volume was measured, and a sample was taken for chemical analysis. The magnesium content was determined by the method of Denis (1922), modified for urine analysis; the calcium, by a modification of the method of Roe and Kahn (1926); the phosphorus, by an adaptation of the method of Fiske and Subbarow (1925); and potassium, by the method described by Fister (1950).

The lambs were observed daily to detect symptoms of urinary calculi. When symptoms were noticed, the lamb was sacrificed and autopsied. At this time the condition of the entire urinary tract was noted and any stones present were collected for chemical analysis. At the conclusion of the experimental period, the remaining sheep were slaughtered. The urinary tracts were removed and examined for the presence of calculi. Those having stones present at slaughter were recorded as calculi cases, along with the lambs already autopsied.

Results and Discussion

During the 100-day period in which they were fed the mixed grass-alfalfa hay diet, the lambs appeared to eat normally and to gain satis-

factorily in body weight. No symptoms of urinary calculi were shown by any of the 80 lambs during the entire pre-experimental period.

Symptoms

The first case of urinary calculi was observed on the 32nd day of the experiment. The symptoms noted proved to be typical of subsequent cases of urinary calculi. Anorexia was the first symptom recognized. Soon thereafter, the animal was observed lying with its rear legs extended out to the side instead of having them up under the body in the normal position. The most specific symptom was the straining by the animal in an attempt to urinate. The hunched back and distended flank region, a result of straining, is a characteristic symptom of urinary calculi. Further, the animals frequently shifted their weight on their rear legs and were observed to stamp their hind feet, as if bothered by flies. They frequently stood with their hind feet placed far to the rear in what appeared to be an attempt to relieve the pressure and pain resulting from the distended bladder. Some were seen to kick at the abdomen. Animals in advanced stages were rarely seen attempting to urinate; they appeared extremely depressed.

During the course of the trial, several lambs displayed typical symptoms of calculi, but their condition improved and they appeared normal. In each case, however, the animal soon developed symptoms again. It was then sacrificed for autopsy which revealed calculi. One animal survived for a period of 16 days before the symptoms recurred, but in most cases only 5 or 6 days elapsed before recurrent symptoms were shown.

At the time of the autopsy, the urinary tract was usually found to be obstructed at the urethral process. The neck of the bladder was the next most common site of obstruction with calculi. At this location, however, the occlusion was caused by a larger stone(s) which apparently had grown by concretion in the bladder. Stones were found predominantly in the bladder. In all cases, except two, bladder stones were noted. Three sheep were found to have stones present in the kidney. In two cases only one kidney was affected (figure 1), and in a third case both kidneys contained calculi.

Occurrence of Calculi

The number of cases of calculi that were produced by each treatment is shown in table 2. During the 124-day period, there was a total of 29 cases of calculi. Upon examination of the urinary tracts taken from

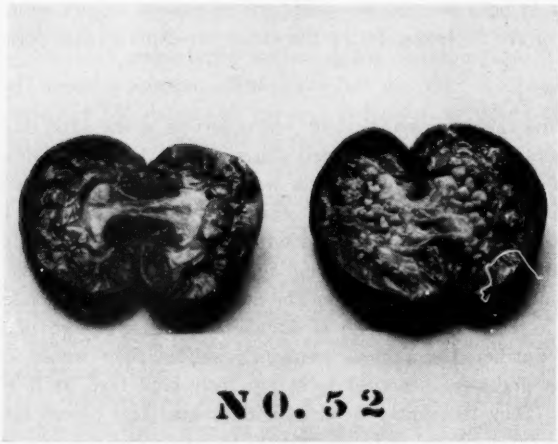

Figure 1. Kidneys from lamb No. 52 at slaughter. Note hypertrophy and calculi present in the kidney on the right.

the 51 remaining sheep at the time of slaughtering, seven more lambs were observed to have developed calculi, making a total of 36.

The effect of the various added minerals on the incidence of calculi is very apparent. The addition of a high level of phophorus alone to the diets of 20 lambs produced only one case of urinary calculi. In previous studies (Lindley *et al.*, 1953; Taysom *et al.*, 1953) involving the production of urinary calculi in sheep by the addition of potassium acid phosphate to the diet, phosphorus was implicated as the factor responsible for this effect. Other than the absence of potassium, a comparison of the diets fed by Taysom *et al.* (1953) and Lindley *et al.* (1953) and those supplemented with phosphoric acid in this study, reveals a close similarity.

TABLE 2. THE EFFECT OF TREATMENT ON THE INCIDENCE OF URINARY CALCULI [a]

Mineral	No beet pulp		Beet pulp		Total
	No molasses	Molasses	No molasses	Molasses	
K_2HPO_4	3	0	4	5	12
H_3PO_4	0	0	0	1	1
K_2CO_3	0	1	2	4	7
$H_3PO_4+K_2CO_3$	2	4	5	5	16
Total	5	5	11	15	36

[a] Five sheep per lot.

The addition of a high level of potassium alone to the diets of 20 sheep produced seven cases of calculi. The difference between seven cases, produced when potassium was added, and one case, when phosphorus was added, was significant ($P<.05$) as shown in table 3. The

TABLE 3. ANALYSIS OF THE OCCURRENCE OF URINARY CALCULI AS AFFECTED BY TREATMENT

Treatment	Animals per treatment	Occurrence of calculi	Significance
H_3PO_4 vs. K_2CO_3	20	1 vs. 7	$P<.05$
K_2CO_3 vs. $K_2CO_3+H_3PO_4$	20	7 vs. 16	$P<.05$
K_2HPO_4 vs. $K_2CO_3+H_3PO_4$	20	12 vs. 16	NS
Phosphorus or potassium vs. phosphorus+potassium	40	8 vs. 28	$P<.01$
No molasses vs. molasses	40	16 vs. 20	NS
No beet pulp vs. beet pulp	40	10 vs. 26	$P<.01$

increased incidence of calculi resulting from the addition of potassium to the diet cannot be accounted for at present.

When both potassium and phosphorus were added together in the diet, in the same chemical form as when included singly, 16 of the 20 sheep developed calculi. The difference between adding these minerals singly or in combination was statistically significant ($P<.01$). That is, more cases of calculi resulted when phosphoric acid and potassium carbonate were added together in the diet than when they were added singly.

Of the 20 sheep receiving potassium and phosphorus in their diet in the form of potassium acid phosphate, 12 developed calculi. This was not significantly different from the 16 cases, in the same number of animals, which developed when potassium and phosphorus were added in the form of potassium carbonate and phosphoric acid.

Thus, it appears that potassium and phosphorus have a synergistic action when both are included in the diet at high levels. Although the mechanism involved is not known, the results of this experiment indicate that a relationship does exist. Lindley *et al.* (1953) and Taysom *et al.* (1953) attributed the increased incidence of calculi that resulted from including potassium acid phosphate in the diet, to the phosphorus. However, it would appear that it was the combination that was responsible.

There were 26 cases of calculi in the 40 lambs receiving beet pulp in their diet, while 10 cases were produced in those not receiving beet

pulp. This difference was statistically significant ($P<.01$) and agrees with results reported by Michael (1910) in which the incidence of calculi was increased by feeding sugar beets in the diet. Also, it is of interest to note that in the studies of Lindley *et al.* (1953), beet pulp was included in their basal ration at the same level as in the experiment reported herein. They reported that 25% of the sheep fed this type of diet developed calculi. Especially noteworthy are the results of Taysom *et al.* (1953) concerning the effect of feeding beet pulp on the incidence of calculi. Although molasses was included with the beet pulp, a comparison of their results with those of the present study indicates a striking similarity. The authors reported that out of 32 lambs receiving a ration containing at least 25% beet pulp, 24 or 75%, developed urinary calculi. This agrees with the 26 out of 40, or 65%, in this study.

It has been shown that the addition of both phosphorus and potassium to the ration resulted in the largest number of cases of calculi, affecting 28 out of 40 wethers. Only one-half of the animals receiving this combination were also receiving beet pulp. Out of the 20 animals receiving phosphorus, potassium, and beet pulp in their diet, 19 developed calculi. This was perhaps the most conclusive result of the entire experiment.

The presence or absence of beet molasses in the diet failed to significantly influence the number of cases of calculi in this experiment. There were 16 cases of calculi among the 40 sheep receiving no molasses in their diet and 20 cases among those being fed molasses.

Urine Analysis

The effects of the various treatments on urinary excretion are shown in table 4. The addition of either molasses or beet pulp to the diet increased the daily volume of urine. Evvard *et al.* (1923) reported an increase in water consumption in lambs fed molasses. Potassium, when added in the form of potassium carbonate, also increased the daily urine volume.

Lindley *et al.* (1953) reported an increase in 24-hour urine volume with the addition of phosphorus to the diet. The addition of phosphorus, as phosphoric acid, in this experiment did not result in a similar effect. The addition of phosphorus with or without potassium, resulted in a higher urinary phosphorus excretion. This was expected and had been reported previously (Lindley *et al.*, 1953). On the other hand, when either molasses or beet pulp was added to the diet the urinary phosphorus excretion was also increased. Further, a significant

TABLE 4. EFFECT OF TREATMENT ON AVERAGE DAILY URINE EXCRETIONS

Items	Mean	Molasses	Beet pulp	Phosphorus	Potassium	Phophorus + potassium
Number of animals	80	40	40	20	20	40
Urine volume, ml.	1541	1842	1726	1254	1772	1569
Urine phosphorus, gm.	.571	.664	.657	.830	.220	.618
Urine potassium, gm.	26.0	31.7	24.2	14.0	36.8	26.7
Urine calcium, gm.	.070	.070	.073	.088	.066	.061
Urine magnesium, gm.	.020	.022	.020	.014	.023	.021

increase ($P<.01$) in the urinary phosphorus resulted from an interaction between beet pulp and molasses (table 5).

Urinary potassium excretion was much higher when either molasses or potassium carbonate was included in the diet. This was not unexpected since beet molasses is a rich source of potassium. Calcium excretion was increased ($P<.01$) by the inclusion of beet pulp in the diet and also by the addition of phosphoric acid. Although the calcium excretion in the urine was higher when phosphoric acid was fed in the diet, the magnesium was lower. On the other hand, magnesium excretion was highest when potassium carbonate was fed.

Calculi Analysis

Of the 36 cases of urinary calculi, there were 28 in which a sufficient number of calculi were collected to allow chemical analysis. The calculi were composed principally of magnesium and phosphorus. This is in accordance with the results reported by several other investigators (Newsom, 1938; Lindley *et al.*, 1953; and Loeschke and Elvehjem, 1954). A complete spectrographic analysis of the mineral content

TABLE 5. ANALYSIS OF VARIANCE OF URINE VOLUME, PHOSPHORUS, POTASSIUM, CALCIUM, AND MAGNESIUM EXCRETIONS

Mean Squares Only

Source	d/f	Volume	Phosphorus	Potassium	Calcium	Magnesium
Total	79					
Beet pulp	1	2735780**	2.270**	263	.00618**	.0001
Molasses	1	7252896**	2.626**	2551**	.00002	.0005*
Beet pulp × molasses	1	12440	2.211**	639*	.00610**	.....
Minerals	3	950319*	4.371**	1746**	.00326**	.0004*
Beet pulp × minerals	3	78330	.376*	231	.00046	.....
Molasses × minerals	3	774896	.591**	245	.00186	.00023
Beet pulp × molasses × minerals	3	221564	.434*	59	.00147	.00026
Error	64	344927	.127	119	.00072	.00011

* $P<.05$, ** $P<.01$.

of the stones was conducted. The major mineral constituents, on a dry-matter basis, are presented in table 6. Sodium, potassium, and calcium each comprised slightly more than 1% of the stones. Other minerals including silicon were present at such a low level as to appear insignificant. Swingle (1953) analysed stones collected from range steers having urinary calculi and found silicon to be the principal constituent.

TABLE 6. AVERAGE MINERAL COMPOSITION OF CALCULI

Mineral	Percent
Aluminum	0.012
Barium	0.071
Calcium	1.149
Copper	0.007
Iron	0.014
Magnesium	15.800[a]
Phosphorus	13.900[a]
Potassium	1.413
Silicon	0.065
Sodium	1.095

[a] Taysom (1953) unpublished.

Discussion

The fact that no symptoms of urinary calculi were observed during the 100-day pre-experimental period appears to be of some significance. Although none of the lambs was kept on the hay diet as a control, the short period of time that elapsed after the lambs were placed on the test diets until the first case of calculi was recorded would appear to be more than a coincidence.

It has been stated that the addition of phosphoric acid to the diet was not predisposing to the formation of urinary calculi in this experiment. Loeschke and Elvehjem (1954) have reported that the addition of 1 gm. of ammonium chloride daily to a diet fed to mink reduced the incidence of calculi. They attributed this prophylactic effect to the change in urinary reaction that resulted. The urine became more acid with the addition of ammonium chloride to the diet.

The reason phosphoric acid, when added to the diet, failed to increase the incidence of calculi is possibly due to a similar effect. That is, the feeding of phosphoric acid at 6 gm. per pound of feed may have resulted in a less alkaline urine. Because magnesium and phosphorus, the principal constituents found in the calculi, are insoluble in an alkaline

solution the effect of decreasing the urine alkalinity should be to prevent the precipitation of these minerals. That the addition of beet pulp or potassium to the diets increased the incidence of calculi while including molasses did not suggest that the explanation for tendency to form calculi is not simply the amount of potassium in the feed. Beet molasses is much higher in potassium than beet pulp. The effect of the diets on urine reaction was not determined in this experiment.

That urinary calculi in sheep can be produced experimentally is demonstrated by the results of this study. This information can be utilized as a valuable tool in studying further the complicated problem of urolithiasis.

Summary

The effects of some dietary factors on the incidence of urinary calculi in sheep and on urinary excretion are reported.

Eighty crossbred white-faced wether lambs were divided into 16 lots of five sheep each and were fed a mixed grass-alfalfa hay for 100 days. Water and salt were available free-choice. During this period, no symptoms of urinary calculi were shown.

Each lot was then placed on one of 16 pelleted concentrate-roughage diets for a period of 124 days. The experiment was of factorial design and the variables were phosphorus, potassium, beet pulp, and beet molasses in the diets.

The occurrence of calculi was influenced greatly by treatment. Thirty-two days after the lambs were fed the experimental diets, the first case of calculi was recorded. A total of 36 cases of calculi was produced during the 124-day test period.

The addition of potassium to the diets of 20 sheep resulted in seven cases of calculi, while a phosphorus addition caused only one case in 20 sheep. This difference was significant ($P<.05$). The addition of both phosphorus and potassium either as potassium acid phosphate or as phosphoric acid and potassium carbonate, resulted in 28 cases in 40 sheep, also a significant ($P<.01$) result.

The inclusion of beet pulp in the diets of 40 sheep, at approximately 25% of the diet, resulted in 26 cases of calculi. Ten cases were found in 40 lambs receiving no beet pulp. The presence of beet molasses at approximately 11% of the diet had no effect on the occurrence of urinary calculi.

The highest incidence of urinary calculi resulted when phosphorus, po-

tassium, and beet pulp were all included in the diet. Out of 20 sheep receiving this type of diet, 19 developed calculi.

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RAISING BEEF CALVES FROM BIRTH ON SYNTHETIC AND WHOLE DRIED MILK WITH AND WITHOUT OXYTETRACYCLINE [1, 2, 3]

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THE results reported in this paper are from a project which was born of necessity—the necessity of eliminating an infection of Johne's disease in the beef cattle herd at the State College of Washington. Because of the extreme susceptibility of young calves to this disease, it seemed highly desirable that they be raised in strict isolation from their dams from the moment of birth.

A considerable amount of work has been done using synthetic milk instead of whole milk fed to calves (Wiese *et al.*, 1947; Arrington and Reaves, 1948; Williams and Knodt, 1950; Wallace *et al.*, 1951; Brumbaugh and Knodt, 1952; Stein *et al.*, 1954). The synthetic milk that was fed consisted of skim milk with other supplements added to make it equivalent to whole milk. It was also found that animal fats homogenized into skim milk were superior to plant oils (Gullickson *et al.*, 1942; Wiese *et al.*, 1947; and Stein *et al.*, 1953).

Certain antibiotics have been used to increase growth and to control diseases in dairy calves. Cason and Voelker (1951) indicated that terramycin (oxytetracycline) might be of value in stimulating the growth rate of dairy calves and in reducing the incidence of scours. Others (MacKay *et al.*, 1952, 1953; Voelker and Jacobson, 1953; Kesler, 1954) obtained significant growth increase in dairy calves from feeding oxytetracycline. On the other hand, there are reports (Murdock *et al.*, 1951; Lassiter *et al.*, 1954; Williams and Jenson, 1954) indicating no significant difference in the growth of dairy calves when oxytetracycline was fed.

The present project provided an opportunity to compare synthetic

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milk with dried whole milk as well as to evaluate the use of antibiotics (oxytetracycline) in promoting growth in beef calves. In addition this project provided a satisfactory means of measuring efficiency of feed utilization for beef calves at an early age.

Experimental Procedure

The animals used in this experiment were 62 calves, involving the Aberdeen-Angus, Hereford, and Shorthorn breeds, from the College beef cattle herd. The experimental design with the number of animals is

TABLE 1. EXPERIMENTAL DESIGN SHOWING THE ALLOTMENT OF ANIMALS

Treatment	No. of calves	
	Male	Female
Dried whole milk	7	7
Dried whole milk with oxytetracycline	10	7
Synthetic milk	9	7
Synthetic milk with oxytetracycline	8	7

shown in table 1. All calves were taken from their dams at birth and before nursing, thoroughly scrubbed and disinfected in the laboratory, and placed under heat lamps to dry. Within each sex, calves were assigned at random to the four treatments. Each animal was stabled in an individual pen and fed separately. Weights were taken at 7-day intervals.

During the first two days of life, each calf received colostrum.[5] Beginning with the third day and continuing until four weeks of age, the calves were fed on the four different milk preparations, in one half gallon bottles equipped with rubber nipples. (figure 1). The formula of the synthetic milk was as follows: Dried skim milk, 78.0; fish solubles, 5.0; corn steep liquor, 0.125; molasses, 0.125; lard, 9.0; dried brewers yeast, 1.5; lecithin, 4.0; vitamin pre-mix 1, 2.05.[6] Milk feeding was at

[5] Colostrum had been obtained from nearby dairies and frozen and stored until needed. Before feeding, it was warmed to body temperature. On the third and fourth days of age, colostrum was mixed with the reconstituted dry whole milk or synthetic milk to minimize digestive disturbances while making the transition to the experimental diets.

[6] Contained per pound: Vitamin A, 15,000 I.U.; Vitamin D_3, 3,500 I.U.; Thiamine HCl, 2.17 mg.; Riboflavin, 4.65 mg.; Niacin, 9.40 mg.; Choline chloride, 400.0 mg.; Pantothenic acid, 27.60 mg.; Pyridoxine, 4.65 mg.; Inositol, 96.0 mg.; Vitamin C, 133.0 mg.; Para-aminobenzoic acid, 2.40 mg.; Vitamin K, 3.3 mg.; Vitamin B_{12}, .045 mg.; Ferric ammonium citrate, .43 gm.; Copper sulfate·$5H_2O$, .02 gm.; Zinc sulfate·$6H_2O$, .0003 gm.; Cobalt sulfate·$2H_2O$, .004 gm.; Magnesium sulfate·$7H_2O$, .75 gm.; Manganese sulfate·H_2O, .03 gm.; Calcium carbonate, 3.5 gm.; Potassium iodide, .025 gm.; Sodium chloride, 1.0 gm. and Potassium chloride, .2 gm.

the rate of 1 lb. of reconstituted milk (reconstituted by adding water until solids equalled 13% by weight) per 10 lb. of body weight of calf.

The oxytetracycline was fed orally (mixed in the milk) at the rate of 25 mg. daily per 100 lb. body weight.

In addition to the milk, alfalfa hay (second cutting) and a calf starter ration were provided free choice from birth. Water was also available at all times. The calf starter ration contained the following ingredients: corn, ground, 200; barley, ground, 150; oats, ground, 200;

Figure 1. Calf sucking from bottle.

linseed oil meal, 180; millrun (wheat mixed feed), 100; dehydrated alfalfa, ground, 50; steamed bone meal, 10; iodized salt, 10.

At four weeks of age, bottle feeding was discontinued and the calves were placed entirely on dry feed. After four weeks of age, the diet consisted of (a) dry whole milk or dry synthetic milk, with or without antibiotic, in keeping with the experimental design; (b) hay, free choice; and (c) calf starter, free choice. The dry whole milk and dry synthetic milk, respectively, were mixed with the calf starter. The amount of milk was limited so that the daily consumption was at the same rate as when liquid milk was fed: 1 lb. of liquid milk to 10 lb. of body weight.

Results and Discussion

One calf died at five days of age; its condition was diagnosed as white muscle disease. Diarrhea (or scours) was encountered in all calves at about 14 days of age. This condition persisted for a period of 3 to 10 days, after which the calves appeared normal. The next set-back

TABLE 2. DAILY RATE OF GAIN (MEANS) OF CALVES FED DRIED-WHOLE MILK VS. SYNTHETIC MILK, WITH AND WITHOUT ANTIBIOTIC BY CUMULATIVE 28-DAY PERIODS

	Whole milk		Whole milk+ antibiotic		Synthetic milk		Synthetic milk+ antibiotic	
	Bulls	Heifers	Bulls	Heifers	Bulls	Heifers	Bulls	Heifers
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
All breeds								
No. of animals	7	7	10	7	9	7	8	7
Birth to:								
28 days	0.47	0.38	0.57	0.56	0.43	0.39	0.57	0.44
56 days	0.76	0.68	0.81	0.83	0.82	0.57	0.86	0.71
84 days	0.95	1.05	1.00	1.07	1.00	0.85	1.22	0.90
112 days	1.16	1.21	1.20	1.20	1.21	1.01	1.33	1.10
140 days	1.37	1.27	1.42	1.39	1.42	1.18	1.49	1.26
168 days	1.51	1.43	1.59	1.50	1.60	1.30	1.67	1.37
180 days	1.59	1.47	1.65	1.51	1.68	1.36	1.73	1.42
Aberdeen-Angus								
No. of animals	6	4	4	4	6	3	5	3
Birth to:								
28 days	0.65	0.56	0.57	0.47	0.70	0.57	0.52	0.54
56 days	0.86	0.82	0.87	0.68	0.94	0.83	0.94	0.73
84 days	1.09	1.07	1.08	1.22	1.17	1.00	1.10	0.86
112 days	1.25	1.18	1.28	1.19	1.39	1.15	1.32	1.07
140 days	1.48	1.44	1.50	1.36	1.56	1.31	1.50	1.22
168 days	1.65	1.53	1.66	1.50	1.72	1.42	1.73	1.30
180 days	1.69	1.58	1.70	1.53	1.75	1.43	1.77	1.34

occurred during the transition period from bottle (liquid) feeding to dry feeding at the end of the first 4 weeks.

Table 2 lists the results of daily gain of the calves from birth, by cumulative 28-day intervals. The first set-back due to the diarrhea is reflected in the rather low average daily gains in each treatment during the first period from birth to 28 days of age.

The analysis of variance (Yates, 1933) for rate of gain by cumulative 28-day periods is given in table 3. It will be noted that oxytetracycline appeared to have some effect on the gains in the first 28-day period but no effect on the gains in any of the subsequent periods. The calves did as well on synthetic milk as on dried whole milk. There was a highly significant difference due to sex. Starting with the period from birth to 112 days of age and continuing until the calves reached 180 days of

TABLE 3. THE ANALYSIS OF VARIANCE FOR RATE OF GAIN, BY CUMULATIVE 28-DAY PERIODS

Breed	Source of variation	Degrees of freedom	Mean squares						
			28 days	56 days	84 days	Birth to: 112 days	140 days	168 days	180 days
All breeds	Oxytetracycline (T)	1	0.0276*	0.0181	0.0145	0.0072	0.0128	0.0105	0.0055
	Milk (M)	1	0.0028	0.0018	0.0013	0.0018	0.0013	0.0010	0.0001
	T×M	1	0.0010	0.0001	0.0050	0.0041	0.0001	0	0
	Sex (S)	1	0.0088	0.0265	0.0112	0.0181*	0.0450**	0.0741**	0.0990**
	T×S	1	0.0001	0.0050	0.0050	0.0008	0.0008	0	0
	M×S	1	0.0006	0.0145	0.0406*	0.0288**	0.0145*	0.0231*	0.0171*
	T×M×S	1	0.0035	0	0.0025	0.0001	0.0005	0	0.0001
	Error	54	0.0068	0.0083	0.0060	0.0039	0.0035	0.0042	0.0031
Aberdeen-Angus	Oxytetracycline	1	0.0181	0.0066	0.0006	0.0015	0.0010	0.0021	0.0015
	Milk	1	0.0018	0.0055	0.0136	0.0001	0.0045	0.0036	0.0055
	T×M	1	0.0002	0.0001	0.0153	0.0045	0.0001	0.0010	0.0001
	Sex	1	0.0313	0.0378	0.0105	0.0528*	0.0530*	0.1275**	0.1326**
	T×S	1	0.0025	0.0078	0.0010	0.0001	0.0078	0.0036	0.0036
	M×S	1	0.0098	0.0010	0.0351	0.0136	0.0153	0.0253	0.0276
	T×M×S	1	0.0032	0.0002	0.0066	0	0.0003	0.0010	0.0003
	Error	27	0.0181	0.0132	0.0185	0.0098	0.0086	0.0098	0.0082

* Significant at 5% level of probability.
** Significant at 1% level of probability.

age, bull calves made faster gains than heifer calves. There was also difference due to the influence of milk on sex, which is difficult to explain. It is noteworthy that there was no difference between the bulls and heifers in the rate of gain for at least the first 12 weeks.

The results of feed intake per pound of body weight of the calves are presented in table 4. Feed intake was calculated on the basis of body

TABLE 4. FEED INTAKE PER POUND OF BODY WEIGHT (MEANS) OF CALVES FED DRIED WHOLE MILK VS. SYNTHETIC MILK, EACH WITH AND WITHOUT OXYTETRACYCLINE, BY CUMULATIVE 28-DAY PERIODS

	Whole milk		Whole milk+ oxytetracycline		Synthetic milk		Synthetic milk+ oxytetracycline	
	Bulls	Heifers	Bulls	Heifers	Bulls	Heifers	Bulls	Heifers
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
All breeds:								
No. of animals	7	7	10	7	9	7	8	7
Birth to:								
28 days	0.44	0.45	0.44	0.45	0.40	0.45	0.42	0.43
56 days	0.92	0.97	0.91	0.99	0.93	0.93	0.92	0.94
84 days	1.43	1.43	1.59	1.53	1.48	1.48	1.43	1.43
112 days	1.64	1.98	1.83	1.98	1.92	1.89	1.86	1.89
140 days	2.03	2.43	2.16	2.42	2.37	2.39	2.26	2.31
168 days	2.50	2.83	2.53	2.83	2.68	2.87	2.64	2.74
180 days	2.69	2.98	2.75	3.06	2.87	2.98	2.81	2.87
Aberdeen-Angus								
No. of animals	6	4	4	4	6	3	5	3
Birth to:								
28 days	0.48	0.48	0.50	0.46	0.43	0.45	0.47	0.54
56 days	0.99	0.98	0.98	0.97	0.93	0.97	0.92	1.04
84 days	1.53	1.45	1.51	1.64	1.45	1.33	1.50	1.48
112 days	1.92	1.92	1.70	1.94	1.88	1.80	2.01	2.10
140 days	2.18	2.34	2.14	2.25	2.34	2.23	2.46	2.47
168 days	2.59	2.75	2.48	2.65	2.71	2.56	2.80	2.89
180 days	2.86	2.95	2.74	2.87	2.89	2.82	2.97	3.03

weight, rather than gain, to allow for the fact that larger calves consume more feed. The efficiency of feed utilization in young calves was very high. The amount of feed consumed (air dry, 7.5% moisture) per pound of body weight increased, as the calves grew older, from an average of 0.44 lb. of feed per pound of body weight for the first 28 days to 2.88 lb. of feed per pound of body weight for the period birth to 180 days.

The analysis of variance for feed intake per pound of body weight by cumulative 28-day periods is given in table 5. The kind of milk used did not affect the amount of feed consumed per pound of body weight. Supplementing the milk with oxytetracycline had no effect on the amount of feed consumed. There was a highly significant difference in feed efficiency due to sex. Starting with the period from birth to 112 days

TABLE 5. THE ANALYSIS OF VARIANCE FOR FEED INTAKE PER POUND OF BODY WEIGHT BY CUMULATIVE 28-DAY PERIODS

Breed	Source of variation	Degrees of freedom	Mean squares						
			Birth to:						
			28 days	56 days	84 days	112 days	140 days	168 days	180 days
All breeds	Oxytetracycline	1	0	0	0.0032	0.0021	0.0006	0.0025	0.0001
	Milk	1	0.0008	0.0006	0.0032	0.0021	0.0105	0.0072	0.0003
	T×M	1	0	0	0.0162	0.0078	0.0120	0.0050	0.0120
	Sex	1	0.0008	0.0028	0.0004	0.0300*	0.0666**	0.1058**	0.0741**
	T×S	1	0.0002	0.0003	0.0004	0.0021	0.0015	0.0018	0.0001
	M×S	1	0.0002	0.0015	0.0004	0.0300*	0.0435*	0.0144	0.0231
	T×M×S	1	0.0002	0	0.0004	0.0078	0.0036	0.0004	0.0006
	Error	54	0.0012	0.0025	0.0084	0.0056	0.0073	0.0136	0.0064
Aberdeen-Angus	Oxytetracycline	1	0.0021	0.0002	0.0171	0.0210	0.0066	0.0055	0.0021
	Milk	1	0.0001	0.0004	0.0171	0.0120	0.0435	0.0300	0.0105
	T×M	1	0.0021	0.0008	0.0001	0.0496	0.0300	0.0496	0.0253
	Sex	1	0.0003	0.0025	0.0010	0.0078	0.0036	0.0091	0.0055
	T×S	1	0	0.0008	0.0120	0.0066	0.0006	0.0078	0.0021
	M×S	1	0.0021	0.0040	0.0045	0.0066	0.0171	0.0190	0.0066
	T×M×S	1	0.0010	0.0008	0.0015	0.0006	0.0036	0.0066	0.0021
	Error	27	0.0029	0.0073	0.0156	0.0152	0.0181	0.0336	0.0152

* Significant at 5% level of probability.
** Significant at 1% level of probability.

of age, the bulls consumed less fed per pound of body weight than did the heifers. There appeared to be some breed differences, since this difference between sexes with regard to feed consumption did not show up in the Aberdeen-Angus breed (table 5).

Summary and Conclusions

Sixty-two beef calves, involving the Aberdeen-Angus, Hereford, and Shorthorn breeds were raised from birth to 180 days of age on synthetic and dried whole milk with and without oxytetracycline. Scouring occurred in all calves at about two weeks of age, and lasted from 3 to 10 days.

There was no significant difference in the rate of gain or in the feed intake per pound of body weight between the two kinds of milk fed.

Oxytetracycline fed at 25 mg. per 100 lb. of body weight appeared to improve the gains in the first 28-day period but had no effect on gains in subsequent periods. Oxytetracycline had no effect on the feed intake per pound of body weight at any period of growth from birth to 180 days of age.

There was no difference in the rate of gain or in the feed intake per pound of body weight between the bulls and the heifers for the first 84 days. However, the bulls gained faster and more efficiently after 84 days of age.

It is evident that beef calves can be successfully raised away from their dams when fed the diets indicated. This is of practical importance in raising orphaned calves, doing away with nurse cows, and controlling disease problems. Of even greater importance is the fact that this method can be used in further research with beef cattle, by controlling one of the greatest variables—the milking ability of the dam and her effect on the calf.

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DEHYDRATED ALFALFA MEAL AS A DIETARY INGREDIENT FOR SWINE

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DEHYDRATED alfalfa meal has had considerable attention and usage as a source of supplementary vitamins and unidentified factors in the nutrition of domestic animals.

For swine, the studies of Fairbanks *et al.* (1945a, 1945b) demonstrated the value of alfalfa meal as a source of water-soluble vitamins in the diet for growth and reproduction. The works of Scott *et al.* (1953) and of Hansen *et al.* (1953) showed conclusively that alfalfa meal is a source of an unidentified growth factor or factors for the baby chick. However, Gard *et al.* (1954) failed to find that 10% dehydrated alfalfa meal in the diet provided the growing pig with an unidentified growth-active element.

Recently alfalfa meal has received some consideration as a source of energy and protein in the diet of swine. In an initial report from the Nevada Station, McCormick and Kidwell (1953) reported that ground alfalfa hay was nearly equal to grain when the ration consisted of 30 to 50% alfalfa. However, later Bohman *et al.* (1953, 1955) have reported that as the level of dietary alfalfa increased from zero to 50% the rate of gain, dressing percentage, depth of backfat, percent bacon belly, and percent fat back decreased significantly while the percent of shoulder, ham, and loin in the carcass, and the weight of stomach and large intestine increased significantly. Likewise, Crampton *et al.* (1954) found that the addition of 45% alfalfa to finishing rations resulted in depressed rate and efficiency of gain with definite improvement in carcass quality.

The objective of the studies reported here was to study the nutritive value of dehydrated alfalfa meal when fed at various levels to growing-fattening swine.

Experimental

Three experiments were conducted with pigs produced in the University of Illinois herd. Previous to the start of the tests all pigs were

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fed adequate diets. A description of the experimental diets is given in table 1.

Thirty-six crossbred pigs of Duroc, Hampshire, and Yorkshire breeding were used in Experiment 1. Six outcome groups of six pigs were formed on the basis of ancestry, weight, and general condition. The pigs of each outcome group were allotted at random to the treatments

TABLE 1. PERCENTAGE COMPOSITION OF DIETS FED

Diet designation	A	B	C	D
Ingredients:				
Ground yellow corn	96.4	86.6	89.5	81.0
Soybean oil meal	...	9.8	...	15.4
Menhaden fish meal	...	...	6.9	...
Steamed bone meal	1.0	1.0	1.0	1.0
Mineral mixture No. 3 [a]	2.0	2.0	2.0	2.0
Vitamin A and D supplement (4000A, 500D)	0.1	0.1	0.1	0.1
Vitamin supplement [b]	0.1	0.1	0.1	0.1
Vitamin B_{12}—antibiotic supplement [c]	0.4	0.4	0.4	0.4
Composition:				
Crude protein	8.81	12.56	12.31	14.05 [d]
Crude fiber	2.36	2.62	2.33	2.53 [d]

[a] The percentage composition of mineral mixture No. 3 was as follows: ground limestone, 40.0; steamed bone meal, 31.2; iodized NaCl, 25.0; $MgCO_3$ 2.0; $FeSO_4 \cdot H_2O$, 1.0; $MnSO_4 \cdot H_2O$, 0.56; $CoCl_2 \cdot 6H_2O$, 0.10; $CuSO_4$, 0.1 and $ZnCO_3$, 0.04.

[b] Guaranteed to contain 2 gm. of riboflavin, 4 gm. of pantothenic acid, 9 gm. of nicotinic acid, and 90 gm. of choline chloride per pound.

[c] Guaranteed to contain 1.8 gm. of chlortetracycline HCl and 1.8 mg. of vitamin B_{12} per pound.

[d] Values were calculated.

as noted in the table of results. Following the six weeks feeding trial the pigs were continued on the diets until they reached a body weight of 200 lb. At the weigh day on which the individual pig weighed nearest to 200 lb., it was removed and slaughtered following a 24-hour fast.

For Experiment 2 forty crossbred pigs of Duroc, Hampshire and Yorkshire breeding were used. Outcome groups of four pigs were formed on the basis of ancestry, weight, and general condition. Pairs of outcome groups were divided randomly between the two sources of supplementary protein used. The pigs of each outcome group were randomly assigned to the four levels of dehydrated alfalfa meal.

Forty crossbred, Hampshire, and Yorkshire pigs were used for Experiment 3. Outcome groups of four pigs were formed on the basis of ancestry, weight, and general condition. Pairs of outcome groups were divided randomly between diets equalized or not equalized for calculated

total digestible nutrients (TDN). Equalization was accomplished by adding 3.2, 6.5, and 9.7% crude corn oil to the diets containing 10, 20 and 30% dehydrated alfalfa meal, respectively. The pigs of each outcome group were allotted randomly to the four levels of dehydrated alfalfa meal.

TABLE 2. RESPONSE OF THE FATTENING PIG TO DEHYDRATED ALFALFA MEAL FED AS A PROTEIN SUPPLEMENT WITH YELLOW CORN

(Experiment 1)

Diet	A	A	A	A	A	B
Alfalfa meal, %	0	10	20	30	40	0
Actual analyzed content, %						
Crude protein	8.81	10.44	12.12	13.75	15.42	12.62
Crude fiber	2.36	3.74	5.10	6.43	7.87	2.58
Feed and gain data:						
No. of pigs	6	6	6	6	6	6
Av. initial wt., lb.	101.5	100.3	100.3	99.3	99.3	100.3
Av. daily gain, lb.	1.20	1.36	1.27[a]	0.85	0.81	1.84
Av. daily feed intake, lb.	5.31	5.96	5.67	4.62	4.87	5.97
Feed per lb. gain, lb.	4.41	4.39	5.25	5.46	6.01	3.26
Slaughter data:						
No. of pigs	5	5	5	3	4	6
Av. liveweight, lb.	200.8	202.2	202.0	199.0	198.5	206.7
Av. empty wt., lb.	194.2	192.4	189.4	190.0	184.5	194.8
Av. dressing percentage[b]	79.2	76.6	77.3	74.9	73.9	78.3
Av. backfat thickness, in.	1.68	1.66	1.75	1.48	1.43	1.64
Length of body, in.	29.2	29.6	28.8	29.2	29.6	29.3
Depth of body, in.	14.2	13.8	13.8	13.8	13.6	13.9
Av. specific gravity	1.0165	1.0209	1.0179	1.0186	1.0264	1.0314

[a] Includes a calculated missing value, since one pig failed to perform normally.
[b] $\frac{\text{Carcass weight}}{\text{Empty weight}} \times 100$.

In each case, the levels of dehydrated alfalfa meal fed replaced an equal level of yellow corn in the control diet. The diets were self-fed *ad libitum* to the treatment groups, which were maintained in concrete pens. The feeding trials were terminated after six weeks. The sample of dehydrated alfalfa meal contained a guaranteed minimum of 17.0% protein and a guaranteed maximum of 27.0% fiber. It contained 2% of stabilized animal fat, 0.01% propyl gallate, and 0.005% citric acid.

Results

The feed, growth, and slaughter data obtained in Experiment 1 are presented in table 2.

With regard to the feed and growth data the control pigs fed the

TABLE 3. ANALYSIS OF VARIANCE OF MEAN DAILY GAINS IN EXPERIMENT 1

Source of variance	d/f	Mean square
Alfalfa levels (A)	5	0.8241**
Outcome groups (G)	5	0.1045
A×G	24	0.0562

** Significant at 1% level.

corn-soybean oil meal diet, which contained 12.6% protein, exhibited normal rate and efficiency of gain. On the other hand, corn plus minerals and vitamins (8.8% protein) failed to support normal performance, which indicates the need for supplementary protein for swine at this stage of growth. The addition of 10% alfalfa meal yielded a slight improvement in rate of gain, but the difference is not statistically significant. Hence, dehydrated alfalfa meal has a limited ability to provide supplementary protein with yellow corn. Although the diet containing 20% alfalfa meal supported performance practically equal to that on diet A, there does appear to be a slight depression of growth as compared to the pigs fed 10% alfalfa meal. Rate of gain of pigs fed 40% alfalfa meal was only 68% of that of pigs fed diet A, and feed efficiency also was poorer. Pigs fed the corn-soybean oil meal diet or the 10% alfalfa meal diet consumed equal average quantities; however, there was a statistically significant ($P<0.01$) difference in rate of gain, thus indicating the marked difference in feed conversion. A summary of the statistical analysis of the gain data is presented in table 3; the necessary difference values for mean daily gains are 0.28 and 0.38 lb. daily for the 5 and 1% levels of probability, respectively.

Since it was not convenient to obtain slaughter values for all indi-

TABLE 4. ANALYSIS OF VARIANCE OF SLAUGHTER VALUES IN EXPERIMENT 1

	Between treatments	Within treatments
d/f	5	22
Source of variance:	Mean square	
Liveweight, lb.	32.56	18.09
Empty weight, lb.	66.22**	13.71
Dressing percentage	17.57**	2.07
Backfat thickness, in.	0.1596	0.0719
Length, in.	0.44	0.56
Depth, in.	0.13	0.14
Specific gravity	0.0001746**	0.0000178

** Significant at 1% level.

viduals of the six outcome groups, the data were treated as though the pigs had been allotted completely at random. This probably yields an inflated experimental error, but still it gives a useful test of treatment effects. The statistical analyses of the slaughter values are summarized in table 4.

Measurements at slaughter reveal a statistically significant effect

TABLE 5. RESPONSE OF THE FATTENING PIG TO VARIOUS LEVELS OF DEHYDRATED ALFALFA MEAL IN CORN-SOYBEAN OIL MEAL (B) AND CORN-FISH MEAL (C) DIETS

(Experiment 2)

Alfalfa meal, %	0	10	20	30	Av.
Av. initial wt., lb.					
Corn-soybean oil meal	90.0	91.0	97.2	94.2	93.1
Corn-fish meal	89.4	89.2	89.2	88.6	89.1
Av.	89.7	90.1	93.2	91.4	91.1
Av. daily gain, lb.					
Corn-soybean oil meal	1.78	1.81	1.55	1.24	1.59
Corn-fish meal	1.69	1.80	1.50	1.21	1.55
Av.	1.73	1.81	1.53	1.23	1.57
Av. daily feed intake, lb.					
Corn-soybean oil meal	6.62	6.75	6.04	5.35	6.19
Corn-fish meal	6.64	6.43	5.97	5.20	6.06
Av.	6.63	6.59	6.01	5.28	6.13
Feed per lb. gain, lb.					
Corn-soybean oil meal	3.73	3.73	3.90	4.32	3.89
Corn-fish meal	3.94	3.56	3.97	4.29	3.90
Av.	3.83	3.65	3.94	4.30	3.90

($P<0.01$) of treatment upon empty weight, dressing percentage, and specific gravity. Since the variations in liveweight were not affected by treatment, the differences in empty weight appear to result from shrinkage during the 24-hour fast. Pigs fed diet A dropped 6.6 lb. in bodyweight; whereas, the remaining groups decreased an average of 11.5 lb. This difference does not appear to be attributable to variations in feed intake. The data show that the addition of alfalfa meal to the diet depressed the dressing percentage; whereas, only the pigs fed diet B appeared to be significantly higher in specific gravity. This indicates a fatter carcass in all pigs fed diet A either with or without additions of alfalfa meal. The values for length and depth of body were not statistically different.

The results of Experiment 2 are presented in table 5. Type of sup-

plementary protein failed to influence the response to levels of dehydrated alfalfa meal. Figures for mean daily gain and feed conversion were similar for the two sources of protein. It is noteworthy that the addition of 10% dehydrated alfalfa meal gave a slight increase in rate of gain over the controls; however, this difference is not statistically significant. In contrast, the substitution of either 20 or 30% dehydrated alfalfa meal for corn depressed the rate of gain, daily feed intake, and

TABLE 6. RESPONSE OF THE GROWING-FATTENING PIG TO VARIOUS LEVELS OF DEHYDRATED ALFALFA MEAL AT TWO TDN SCHEDULES (DIET D)

Alfalfa meal, %	0	10	20	30	Av.
Av. initial wt., lb.					
Unequal TDN	60.0	60.2	64.2	64.0	62.1
Equal TDN	63.8	59.8	60.6	63.0	61.8
Av.	61.9	60.0	62.4	63.5	62.0
Av. daily gain, lb.					
Unequal TDN	1.56	1.58	1.20	0.98	1.33
Equal TDN	1.63	1.63	1.35	0.96	1.39
Av.	1.59	1.60	1.27	0.97	1.36
Av. daily feed intake, lb.					
Unequal TDN	4.90	4.70	4.22	4.72	4.64
Equal TDN	4.58	5.20	3.94	2.85	4.14
Av.	4.74	4.95	4.08	3.79	4.39
Feed per lb. gain, lb.					
Unequal TDN	3.15	2.97	3.53	4.81	3.49
Equal TDN	2.81	3.19	2.91	2.98	2.98
Av.	2.98	3.08	3.20	3.91	3.24

efficiency of feed utilization. The mean daily gains were decreased 12 and 29%, respectively, by the substitution of 20 and 30% dehydrated alfalfa meal in the control diet.

The results of Experiment 3 are presented in table 6. It should be observed that the initial weight of the animals was 62.0 lb., which is lower than in the previous tests. The statistical analysis showed a lack of interaction between alfalfa levels and TDN schedule upon the mean daily gains. However, again the levels of dehydrated alfalfa meal produced a statistically significant ($P<0.01$) effect upon the daily gains. Relative to the gains of pigs fed diet D, 10% alfalfa meal had no effect; whereas, 20 and 30% alfalfa meal depressed the rate of gain 20 and 39%, respectively. The chief items of interest in the test are the daily feed intake and the feed conversion. Pigs on the equalized TDN

schedule decreased feed consumption markedly at the 20 and 30% levels of alfalfa meal, but the efficiency of feed utilization appeared to be unaffected. In contrast, on the unequalized TDN schedule 20 and 30% alfalfa meal decreased the efficiency of feed conversion.

A summary of the statistical analyses of the rate of gain obtained in Experiments 2 and 3 is presented in table 7.

TABLE 7. ANALYSIS OF VARIANCE OF MEAN DAILY GAINS IN EXPERIMENTS 2 AND 3

Source of variance	d/f	Mean square	
		Experiment 2	Experiment 3
Type of protein or TDN schedule (T)	1	0.0165	0.0366
Pair groups (P)	4	0.1442	0.3131
T×P	4	0.0363	0.1596*
Alfalfa levels (A)	3	0.6799**	0.9120**
A×T	3	0.0035	0.0143
A×P	12	0.0042	0.0860*
A×T×P	12	0.1012	0.0260

* Significant at 5% level.
** Significant at 1% level.

Discussion

Based upon the amino acid content of the alfalfa plant as reported by Singleton *et al.* (1952) it is reasonable to assume that dehydrated alfalfa meal would supplement the protein of yellow corn for the pig. The Purdue workers observed that alfalfa contains 0.82% lysine and 0.29% tryptophan, and of course, these are the amino acids so notably deficient in corn protein. However, the results presented here indicate that alfalfa meal has a very limited ability to complement the protein of corn in swine nutrition. When tested with the rat fed two levels of casein as the source of protein, Meyer (1954) reported that the addition of 38% alfalfa to the diet improved the nitrogen retention values. It is probable that the first-limiting amino acids in the rat studies were the sulfur-bearing amino acids; whereas, in the test reported here lysine and tryptophan are undoubtedly the limiting amino acids. This variation in the diets could well lead to different responses to alfalfa meal.

Previous attempts by Bohman *et al.* (1953, 1955) to incorporate high levels of alfalfa meal into practical swine diets have resulted in depressed rate and efficiency of gain when levels from 10 up to 50% alfalfa meal were fed to pigs from weaning to market weight in drylot. With the weanling pig the Nevada workers observed that 10% of

alfalfa meal in the diet depressed the rate and efficiency of gain; similar observations were reported by Gard *et al.* (1955). Hence, it is notable that the heavier pig (60 to 100 lb.) can tolerate 10% of alfalfa meal in the diet without a depressing effect upon the rate and efficiency of gain.

A study of the levels of alfalfa meal which depressed performance in the presence or absence of supplementary protein further indicate that alfalfa meal contributed some required amino acids for the pig. The minimum level of alfalfa meal which produced an inhibition of performance was 30% in the absence of supplementary protein and 20% in the presence of such a protein. This difference in response also suggests that alfalfa meal has some value as a supplementary protein. In the absence of supplementary protein alfalfa meal is apparently contributing to the amino acid nutrition of the pig, thus yielding a slight growth response that overshadows any growth inhibition.

The absence of an interaction between the type of supplementary protein and levels of alfalfa has at least one important aspect. It relates to amino acids in the mechanism of the growth inhibition produced by high levels of alfalfa meal. Since the studies of Singleton *et al.* (1952) show that alfalfa contains only 0.25% methionine, it might be postulated that a deficiency of methionine occurs as increasing quantities replace corn in a corn-soybean oil meal diet. However, this does not appear to contribute to the growth depression since the response is identical with menhaden fish meal as the supplementary protein. Menhaden fish meal contains about three times the level of methionine in soybean oil meal.

Peterson (1950a, 1950b) reported that the addition of 4% cottonseed oil and 1% cholesterol completely counteracted the growth depression produced by 20% alfalfa meal in a chick diet. He felt that caloric density of the diet was not involved, since the addition of cottonseed oil alone had no effect on the inhibition. Figures for the efficiency of feed utilization were not reported. Also with the chick, Kodras *et al.* (1951) reported that the addition of 1% cholesterol alone completely counteracted the depressing effect of alfalfa upon the rate and efficiency of gain. In addition, they failed to find evidence that fiber level or palatability of the alfalfa was involved. Particularly, the studies of Peterson suggested that the inhibitory action of alfalfa was due to the presence of saponins, and the growth enhancement produced by cholesterol might be due to the formation of an insoluble sterol-saponin compound in the digestive tract.

Contrary to the findings in chick nutrition, the data presented here

suggest that the digestible energy content of the diet and feed intake are factors in the inhibitory effect of alfalfa for swine. The addition of corn oil to equalize total digestible nutrient content of the diet appeared to prevent the decrease in efficiency, but not the decrease in rate of gain, which is produced by alfalfa. This finding indicates that the decrease in rate of gain on such a diet is largely a result of the depressed feed intake.

Summary

Three experiments were conducted with swine to study dehydrated alfalfa meal as a supplementary source of protein and as an energy replacement for yellow corn in the diet. Growing-fattening pigs were fed diets containing practical ingredients for a six week period in drylot.

With a diet containing 8.8% protein which supported suboptimum gains in the fattening pig, additions of 10 or 20% alfalfa meal had a very limited ability to provide supplementary protein and increase gains; levels of 30 and 40% alfalfa meal markedly depressed the rate and efficiency of gain. As compared to a standard diet, liveweight shrinkage prior to slaughter was lower on the low-protein diet. Specific gravity of carcasses of pigs fed the standard diet was higher than for those fed the low-protein diet either with or without alfalfa meal. In addition, levels of 10 to 40% alfalfa meal added to the low-protein diet decreased the dressing percentage.

In the presence of adequate protein, dietary levels of alfalfa meal of 20% or greater depressed the rate and efficiency of gain, and this inhibition was similar with either soybean oil meal or menhaden fish meal as the source of supplementary protein with yellow corn. When levels of 20 or 30% alfalfa meal replaced yellow corn, the decrease in efficiency of gain but not that in rate of gain was completely eliminated by the addition of corn oil to equalize the calculated digestible nutrient content of the diets.

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THE INHIBITORY EFFECT OF DEHYDRATED ALFALFA MEAL IN THE DIET OF SWINE

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A DEPRESSION of the rate and efficiency of gain in swine fed levels of 10% or more of dehydrated alfalfa meal has been observed by Krider *et al.* (1947), by Bohman *et al.* (1953, 1955), by Gard *et al.* (1955), and by Becker *et al.* (1956). However, only meager data have been collected to clarify the nature of this inhibitory effect. Evidence presented by Gard *et al.* (1955) indicates that the crude fiber of alfalfa meal *per se* is not responsible for the inhibition. Another report by Becker *et al.* (1956) suggests that the diet containing alfalfa has its depressing effect by way of a lowered available energy content and lowered total intake.

Students of chick nutrition have made considerable progress in elucidating the growth-depressing effect of alfalfa for the chick. Peterson (1950a) found that a growth inhibitor which simulates the effects of a purified saponin can be extracted from alfalfa meal with hot water. In addition, Peterson (1950b) reported that the ingestion of 1% cholesterol or certain plant sterols, and 4% cottonseed oil, counteracted the growth depression resulting from the alfalfa meal, the hot-water extract of alfalfa, or the purified saponin. Since cottonseed oil alone had no effect on the inhibition, it was felt that caloric density of the diet was not involved. Kodras *et al.* (1951) observed that 1% cholesterol alone neutralized the depression of rate and efficiency of gain, and furthermore they failed to find that fiber level or palatability of alfalfa were involved. These studies have led to the idea that the growth depressing effect of alfalfa is due to saponins and that sterols counteract it by the formation of an insoluble sterol-saponin compound in the digestive tract.

The objective of the studies presented here was to clarify the nature of the inhibitory effect of dehydrated alfalfa meal on the rate and efficiency of gain in swine.

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Experimental

Four experiments were conducted with pigs produced in the University of Illinois herd. Previous to the start of the tests all pigs were fed adequate diets. Ingredients and composition of the experimental diets are given in table 1. Total digestible nutrient (TDN) content of the diets was calculated using the digestibility figures of the feedstuffs for swine as summarized by Schneider (1947).

TABLE 1. PERCENTAGE COMPOSITION OF DIETS USED

Diet designation	A	B	C	D	E	F
Ingredients:						
Ground yellow corn	76.0	61.0	46.0	55.8	35.6	40.0
Soybean oil meal	20.4	20.4	20.4	20.4	20.4	16.1
Dehydrated alfalfa meal	....	15.0	30.0	15.0	30.0	30.0
Refined corn oil	....	....	....	5.2	10.4	10.3
Steamed bone meal	1.0	1.0	1.0	1.0	1.0	1.0
Mineral mixture No. 3 [a]	2.0	2.0	2.0	2.0	2.0	2.0
Vitamin A and D supplement (4000A–500D)	0.1	0.1	0.1	0.1	0.1	0.1
Vitamin supplement [a]	0.1	0.1	0.1	0.1	0.1	0.1
Vitamin B_{12}-antibiotic supplement [a]	0.4	0.4	0.4	0.4	0.4	0.4
DPPD [b]	0.025	0.025	0.025	0.025	0.025	0.025
Composition:						
Crude protein, %	16.94	18.38	20.06	18.19	18.56	17.75
Crude fiber, %	3.37	6.08	8.57	6.46	9.97	9.49
Ether extract, %	3.57	3.40	3.33	8.54	13.07	13.27
Calculated total digestible nutrients, %	75.7	68.2	60.6	75.7	75.7	75.7
Gross energy (cal. per gm.)	3837.	3833.	3880.	4128.	4446.	4426.

[a] Becker; *et al.* (1956).

[b] N,N¹-diphenyl phenylenediamine. Manufactured by Distillation Products Industries, Eastman Organic Chemicals Department, Rochester, New York.

Forty-two Hampshire or crossbred pigs were used in Experiment 1. Seven outcome groups of six pigs were formed on the basis of ancestry, weight, and general condition. The pigs of each group were allotted at random to the six treatments indicated in table 2. The diets were self fed *ad libitum* to the treatment groups maintained in concrete pens. The experimental period was 41 days. Concurrently, Experiment 2 was conducted with crossbred pigs of Duroc, Hampshire, and Yorkshire breeding. Thirty-six pigs were divided into six outcome groups on the basis of ancestry, weight, and condition, and the pigs of each group were randomly allotted to the same treatments. The pigs were individually hand fed twice daily in individual feeding crates according to the equal feeding technique described by Mitchell and Beadles (1930). The feed intake was equalized within the outcome group at

that of the poorest eating pig within the group. The test period was 43 days.

Experiment 3 was conducted with 36 crossbred pigs of Duroc, Hampshire, and Yorkshire breeding. Six pigs of each outcome group, equalized for ancestry, weight, and general condition, were allotted at random to the three treatments presented in the table of results. The diets

TABLE 2. RESPONSE OF THE WEANLING PIG TO DEHYDRATED ALFALFA MEAL IN DIETS EQUALIZED OR NOT EQUALIZED FOR TOTAL DIGESTIBLE NUTRIENTS

(Experiments 1 and 2)

Diet fed	A	B	C	D	E	F
Treatment	Corn-soybean oil meal	15% Alfalfa meal	30% Alfalfa meal	15% Alfalfa meal plus 5.2% corn oil	30% Alfalfa meal plus 10.4% corn oil	(E) minus 4.3% soybean oil meal
Experiment 1—*Ad libitum* fed						
No. of pigs	7	7	7	7	7	7
Av. initial wt., lb.	37.6	38.3	35.7	37.3	39.9	36.6
Av. daily gain, lb.	1.47	1.29	0.96	1.26	1.04	1.00
Av. daily feed intake, lb.	3.97	3.50	3.56[a]	3.72	3.13	3.06
Feed per lb. gain, lb.	2.70	2.72	3.70	2.96	3.01	3.06
Experiment 2—Equal fed						
No. of pigs	6	6	6	6	6	6
Av. initial wt., lb.	47.7	42.0	44.2	44.8	44.8	44.7
Av. daily gain, lb.	0.81	0.73	0.65	0.76	0.81	0.78
Av. daily feed intake, lb.	2.09	2.09	2.09	2.09	2.09	2.09
Feed per lb. gain, lb.	2.62	2.87	3.24	2.78	2.59	2.71

[a] This value is somewhat higher than the actual intake, since the pigs persisted in wasting the diet.

were self fed *ad libitum* to the treatment groups in concrete pens for a period of 42 days.

In Experiment 4, twenty-one weanling pigs of crossbred, Hampshire, or Yorkshire breeding were used. Seven outcome groups of three pigs were formed on the basis of ancestry, weight, and general condition. The pigs of each outcome group were allotted at random to the treatments as noted in the table of results. The diets were self-fed *ad libitum* to the treatment groups in concrete pens for a period of 18 days.

In all tests, the same sample of dehydrated alfalfa meal was used. It was procured from a local dehydrating company and was considered to be an average product. The alfalfa meal contained no additive and it was guaranteed to contain a minimum of 17.0% protein and a maximum of 27.0% fiber. The corn oil was a highly refined product obtained

from A. E. Staley Mfg. Co., Decatur, Illinois, and the cholesterol was USP grade and manufactured by Wilson and Company, Chicago, Illinois.

Results

The gain and feed data obtained in Experiment 1 and 2 are presented in table 2.

Under an *ad libitum* feeding regimen (Experiment 1), weanling pigs fed a corn-soybean oil meal diet displayed satisfactory rate and efficiency of gain. Analysis of variance, presented in table 3, shows that the treatments produced a highly significant ($P<0.01$) effect upon the mean daily gains; the necessary difference values being 0.16 or 0.22 lb. daily at the 5 or 1% levels of probability, respectively. The addition of 15 or 30% alfalfa meal in the diet depressed the rate of gain 12 or 35%, respectively. There was a similar effect upon the daily feed intake. In regard to efficiency of feed utilization, 15% alfalfa meal had no effect, but 30% alfalfa meal decreased feed efficiency although the value reported is too high because of feed wastage. When corn oil was added with the alfalfa meal to maintain the TDN level at that of the control diet, 15 or 30% alfalfa still depressed gains as much as without oil. The values for feed conversion are not clear cut, but an improvement was noted when oil was added to the diet containing 30% alfalfa meal. The similarity of performance on diets E and F indicate that dehydrated alfalfa and corn can replace 21% of the soybean oil meal in such a diet. The effect of alfalfa meal, in either the presence or absence of corn oil, was to decrease the average daily gain 0.0159 ± 0.00085 lb. per 1% of alfalfa meal. Corn oil gave no appreciable effect.

TABLE 3. ANALYSIS OF VARIANCE OF MEAN DAILY GAINS IN EXPERIMENT 1 AND 2

	Experiment 1		Experiment 2	
Source of variance	d/f	Mean square	d/f	Mean square
Treatments (T)	5	0.2799**	5	0.0201**
Outcome groups (G)	6	0.0433	5	0.0471**
T×G	30	0.0222	25	0.0041

** Significant at 1% level.

When pigs were equally fed (Experiment 2) the same diets, the general level of performance was considerably lower as a result of the

feeding method. The analysis of variance for mean daily gains is presented in table 3; the necessary difference values being 0.08 or 0.10 lb. daily at the 5 or 1% levels of probability, respectively. Additions of 15 or 30% alfalfa without corn oil produced a clear-cut depression in rate of gain and efficiency of feed utilization. On the other

TABLE 4. RESPONSE OF WEANLING PIGS TO THE ADDITION OF CHOLESTEROL IN A CORN-SOYBEAN OIL MEAL DIET WITH AND WITHOUT ALFALFA MEAL OR ALFALFA MEAL AND CORN OIL

(Experiment 3)

Diet fed	A	C	E	
Treatment	Corn-soybean oil meal	30% Alfalfa meal	30% Alfalfa meal and 10.4% corn oil	Av.
Av. initial wt., lb.				
—Cholesterol	34.2	31.7	36.5	34.1
+Cholesterol	35.8	35.3	32.2	34.4
Av.	35.0	33.5	34.3	34.3
Av. daily gain, lb.				
—Cholesterol	1.51	0.84	1.14	1.16
+Cholesterol	1.56	0.97	1.16	1.23
Av.	1.54	0.90	1.15	1.20
Av. daily feed intake, lb.				
—Cholesterol	3.77	2.68	3.14	3.20
+Cholesterol	4.13	3.00	2.91	3.35
Av.	3.95	2.84	3.02	3.27
Feed per lb. gain, lb.				
—Cholesterol	2.49	3.20	2.76	2.75
+Cholesterol	2.64	3.08	2.50	2.71
Av.	2.57	3.14	2.63	2.73

hand, when diets with 15 or 30% alfalfa meal were equalized for TDN by the addition of corn oil, the alfalfa meal exerted no influence upon the performance. Again, performance on diets E and F was similar. The effect of alfalfa meal in the absence of corn oil was to depress the average gain 0.00449 ± 0.00048 lb. per 1% of alfalfa meal; whereas, in the presence of corn oil, the gain was increased by 0.00059 ± 0.00048 lb. per 1% of alfalfa meal.

The results of Experiment 3 are presented in table 4. The analysis

TABLE 5. ANALYSIS OF VARIANCE OF MEAN DAILY GAINS IN EXPERIMENT 3

Source of variance	d/f	Mean square
Treatments (T)	5	0.5015**
Cholesterol (C)	1	0.0442
Alfalfa-corn oil (A)	2	1.2217**
C×A	2	0.0100
Outcome groups	5	0.1058**
T×G	25	0.0118

** Significant at 1% level.

of variance in table 5 shows a higly significant ($P<0.01$) effect for the alfalfa meal-corn oil treatments. As compared to the control, the diet with 30% alfalfa meal decreased daily gains 42%; whereas, the combination of alfalfa meal and 10.4% corn oil depressed gains 25%. The beneficial effect of corn oil upor daily gains was statistically significant. In addition it improved the efficiency of feed utilization to a level equal to that obtained with the corn-soybean oil meal diet. The response to cholesterol supplementation only approached statistical significance ($P=0.063$), its effect appearing greatest with the 30% alfalfa meal diet without corn oil.

The results and analysis of variance of the mean daily gains in Experiment 4 are presented in tables 6 and 7, respectively. The necessary difference values at the 5 or 1% level of probability were 0.15 or 0.21 lb. daily, respectively. The addition of 1% cholesterol to the corn-soybean oil meal diet exerted a slight beneficial effect which was not statistically significant. However, 2% cholesterol produced a significant decrease in rate of gain, feed intake, and feed efficiency.

TABLE 6. RESPONSE OF WEANLING PIGS TO ADDITIONS OF CHOLESTEROL TO A CORN-SOYBEAN OIL MEAL DIET

(Experiment 4)

Treatment	Diet A	Diet A plus 1% cholesterol	Diet A plus 2% cholesterol
No. of pigs	7[a]	7	7
Av. initial wt., lb.	24.7	25.3	23.4
Av. daily gain, lb.	0.98	1.06	0.77
Av. daily feed intake, lb.	2.12	2.17	1.73
Feed per lb. gain, lb.	2.08	2.04	2.25

[a] Includes a calculated missing value for one pig which escaped from the experimental pen.

TABLE 7. ANALYSIS OF VARIANCE OF MEAN DAILY GAINS IN EXPERIMENT 4

Source of variance	d/f	Mean square
Cholesterol levels (C)	2	0.1625**
Outcome groups (G)	6	0.2090**
C×G	11[a]	0.0161

[a] One missing value (see table 6).
** Significant at 1% level.

Discussion

From the practical viewpoint, it is important to note that the levels of dehydrated alfalfa meal employed here were higher than normally recommended for maximum growth in swine.

Our findings agree with the results of earlier workers which showed that 10% or more of alfalfa meal in the diet depressed the rate of gain, feed intake, and feed efficiency in the weanling pig. In addition, it is noteworthy that the effect of corn oil reported in another paper by Becker *et al.* (1956) has been verified in this study. That is, the addition of corn oil to the alfalfa meal diets to equalize TDN values resulted in little or no effect upon the depression in rate of gain and feed intake but it did prevent the usual depression in efficiency of feed utilization. With the chick, Peterson (1950b) observed that the addition of 4% cottonseed oil to a 20% alfalfa meal diet gave a 16% increase in gain, which was still considerably less than normal. He did not report data for efficiency of feed utilization. The beneficial influence of corn oil upon the feed efficiency of pigs fed alfalfa meal indicates that caloric density plays a role in the inhibitory effect.

The results of the equal feeding studies suggest that level of feed intake may also be a factor in the depressing action of alfalfa meal in the diet of swine. Diets with alfalfa meal which were corrected for TDN by additions of corn oil supported rate and efficiency of gain equal to that obtained with the corn-soybean oil meal diet. On the other hand, under *ad libitum* feeding the rate of gain showed little or no improvement when the alfalfa meal diets were increased in TDN content. Thus it would appear that the pig registers the same distinct dislike for alfalfa meal as noted previously in the chick by Graham (1932) and by Dove (1935). Furthermore, our data agree with the findings reported by Card (1951). He observed that when the energy content of the diets was alike and feed consumption was equalized that there was no difference in the growth of chicks fed 0, 10, 20% dehydrated alfalfa

meal that had consistently depressed growth when fed *ad libitum* at a 10% level.

In view of the results with the chick, it was quite surprising that the pig responded so little to the addition of cholesterol to the alfalfa meal diets. Peterson (1950b) observed that 1% cholesterol or plant sterols plus 4% cottonseed oil almost completely counteracted the growth-depressing effect of alfalfa meal on the chick. In addition, a report by Kodras *et al.* (1951) showed that 1% cholesterol alone would overcome the inhibition by alfalfa meal in the fowl. It was suggested by Peterson (1950b) that, in the chick, sterols inactivate alfalfa saponins, which were demonstrated to have growth-inhibiting activity by Heywang and Bird (1954), by the formation of an insoluble sterol-saponin compound. Apparently such a reaction, if it occurs at all, is relatively unimportant in the pig, and the inhibitory effect of alfalfa meal must be explained on a different basis for this species.

Failure of the pig to respond to cholesterol additions in an alfalfa diet increases the likelihood that corn oil improves feed efficiency through its caloric content. At any rate, it seems unlikely that corn oil is contributing sterols which exert a beneficial effect. Anderson and Moore (1923) reported that refined edible corn oil contains 1.68% unsaponifiable matter consisting largely of phytosterols similar to sitosterol. At this rate the addition of 10.4% corn oil in our studies added only 0.17% phytosterols to the diet.

The complete counteraction of the inhibition of performance by corn oil additions and equal feeding strongly suggests that TDN content of the diet and level of feed intake are primary factors in the inhibitory mechanism of alfalfa meal for the pig. In this regard, Fisher *et al.* (1954) reported that growth inhibition in the chick resulting from 40% alfalfa meal in the diet cannot be explained solely on the basis that alfalfa contains atoxic factor.

The reaction of the pig to cholesterol additions in a corn-soybean oil meal diet is interesting. Cholesterol at the 1% level produced a slight but no statistically significant increase in rate of gain in two trials. Potter and Kummerow (1954) observed a chemical similarity and chick growth inhibiting effects of the saponins found in alfalfa and soybeans. Hence, it is notable that 1% cholesterol exerted only a very slight effect, if any, in a diet containing a soybean product, although it is assumed that considerable saponin is hydrolyzed to non-toxic genins by the heat treatment applied in soybean oil meal production.

So far as the authors are aware, a growth-depressing effect of cholesterol, which was obtained here when fed at the 2% level, has not been reported previously.

Summary

Four feeding trials were conducted to clarify the nature of the inhibitory effect of dehydrated alfalfa meal on the rate and efficiency of gain in swine. Weanling pigs fed in drylot were used in the tests.

Dehydrated alfalfa meal was added as a replacement for yellow corn in a corn-soybean oil meal diet at 15 and 30% levels, and also with additions of refined corn oil to yield calculated TDN values equal to the control. When 15 and 30% alfalfa meal was added to the diet a significant decline in performance resulted with either an *ad libitum* or an equal feeding regimen. With equal feeding the corn oil completely counteracted the depression in rate and efficiency of gain produced by alfalfa meal. With *ad libitum* feeding, corn oil improved the efficiency of feed utilization, but had no effect upon rate of gain.

In another *ad libitum*-fed test, 1% cholesterol was added to the corn-soybean oil meal diet and to the 30% alfalfa meal diet with and without corn oil. The effect of cholesterol to improve rate and efficiency of gain, which approached statistical significance, was greatest with the 30% alfalfa meal diet without added corn oil. In this test corn oil with the alfalfa meal diet had a slight but statistically significant effect upon the rate of gain and improved feed efficiency.

The addition of 1% cholesterol to the corn-soybean oil meal diet gave a slight increase in gain which was not statistically significant. However, 2% cholesterol in such a diet caused significant inhibition of rate of gain, feed intake, and feed efficiency.

It appears that a majority of the growth-depressing property of dehydrated alfalfa meal is due to a lowered TDN content of the diet and to a lowered feed intake by the pig.

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THE EFFECT OF FEEDING DEHYDRATED ALFALFA LEAF MEAL AND TRACE MINERALS TO GROWING BEEF CALVES FED POOR QUALITY PRAIRIE HAY [1]

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ALFALFA hay and leaf meal have long been recognized by cattle feeders as supplements to low quality roughages. Numerous studies by Burroughs *et al.* (1950), Chappel *et al.* (1952), and Tillman *et al.* (1954), have shown beneficial effects through increased digestion, when ruminant rations composed of low quality roughages were supplemented with alfalfa hay or alfalfa ash. Beeson and Perry (1952) noted that performance of growing steers was improved by replacing two pounds of corn cobs with two pounds of alfalfa meal. Bentley *et al.* (1952) increased daily gain of fattening steers by replacing soybean oil meal with dehydrated alfalfa leaf meal. According to Klosterman *et al.* (1953) the ash of dehydrated alfalfa leaf meal, molasses fermentation solubles or a trace mineral supplement increased the gains of steers fed principally corn and cob meal supplemented with poor quality roughage.

Other workers have not reported favorable results. Plumlee (1953) found that twin beef calves receiving a ration largely composed of corn cobs, ate less and grew at a slower rate when trace minerals were added. Tillman *et al.* (1954) reported that neither alfalfa ash nor a complete mineral mixture improved the digestibility of low quality prairie hay.

The relation of carotene intake to gain and to blood serum levels of carotene and vitamin A has been studied by several investigators. Guilbert and Hart (1935) showed that carotene intake at the rate of 29 mcg. per kilogram of body weight daily did not allow for storage of this vitamin or cure deficiency symptoms and permit normal weight increase. Guilbert *et al.* (1940) reported good growth rates at a daily carotene intake of 25 to 30 mcg. of carotene per kilogram of live weight. Bechtel and Ward (1936) and Frey *et al.* (1947) reported low daily gains from cattle receiving rations low in carotene.

The Gulf Coast area of Texas grows large quantities of prairie hay of relatively poor quality. This study was designed to determine the

[1] The cooperation of the American Dehydrators Association and the Calcium Carbonate Company is greatfully acknowledged.
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feasibility of supplementing very poor quality prairie hay with alfalfa leaf meal and trace minerals for growing beef calves.

Experimental

Fifty Hereford steer calves were divided into five groups of ten as nearly alike as possible with regard to weight and grade. These steers were placed on a 100-day growth study to determine the effect of dehydrated alfalfa leaf meal and trace minerals on growth rate and feed efficiency of steers fed rations containing a high percentage of poor quality roughage. The roughage fed during this study was previously found to be lacking in palatability and to produce a low growth rate. Dehydrated alfalfa leaf meal, grown and processed in the Brazos River Bottom near Mumford, Texas, was added to the basal ration in varying quantities at the expense of prairie hay in each ration except that for group 5, which received a trace mineral mixture. In addition to the prairie hay and alfalfa leaf meal, each ration contained 4 lb. of ground milo and 2 lb. of cottonseed meal.

The rations fed were as follows: Group 1, prairie hay, free choice, plus 4 lb. of ground milo grain and 2 lb. of cottonseed meal; Group 2, same as Group 1, except 1 lb. of dehydrated alfalfa leaf meal substituted for 1 lb. of prairie hay; Group 3, same as Group 1, except 2 lb. of dehydrated alfalfa leaf meal substituted for 2 lb. of prairie hay; Group 4, same as Group 1, except 3 lb. of dehydrated alfalfa leaf meal substituted for 3 lb. of prairie hay; Group 5, same as Group 1 except a trace mineral mixture containing 20.0% $MnSO_4$, 40.0% $FeSO_4$, 0.933% $CoCO_4$, 2.0% $CuSO_4$, and 0.589% $ZnSO_4$ was added at a level of 0.5% of the concentrate.

Each group of steers received approximately the same level of total feed daily. All groups received equal parts of salt and steamed bone meal, free choice.

The design of the experiment made it possible to determine the effects of three levels of dehydrated alfalfa leaf meal on blood levels of carotene in the same beef steers which were fed the low quality prairie hay during the growth phase. Blood samples were drawn for carotene determinations from 10 animals taken at random from the 50 animals at the beginning of the experiment. At the conclusion of the growing period, blood samples were drawn from all steers and the same determinations were made. The method of analysis used was the

Kimble method of colorimetric analysis as recommended by Gyorgy (1951). During the growth study, samples of the ration were taken periodically and carotene determinations were made.

TABLE 1. THE EFFECTS OF VARIOUS LEVELS OF DEHYDRATED ALFALFA LEAF MEAL AND TRACE MINERALS ON PERFORMANCE OF HEREFORD STEER CALVES FED POOR QUALITY PRAIRIE HAY FOR A 100-DAY PERIOD

Group number	1	2	3	4	5
Number steers per group	10	10	10	10	10
Variable—alfalfa leaf meal	0	1 lb.	2 lb.	3 lb.	Trace mineral
Averages in pounds per steer					
Initial weight	442.9	444.2	443.8	443.9	445.1
Final weight	557.6	571.6	574.3	579.2	556.6
Total gain	114.7	127.4	130.5	135.3	111.5
Daily gain	1.15	1.27	1.31	1.35	1.12
Average daily ration, lb.					
Cottonseed meal	2.00	2.00	2.00	2.00	2.00
Ground sorghum grain	3.89	3.89	3.89	3.89	3.89
Prairie hay (poor quality)	8.12	7.12	6.14	5.10	8.06
Dehydrated alfalfa leaf meal	....	1.00	1.98	2.97	....
Mineral mixture	0.15[a]	0.16[a]	0.20[a]	0.20[a]	0.10
Digestible protein	1.71	1.78	1.85	1.92	1.70
Calculated net energy, therms	6.69	6.88	7.06	7.24	6.67
Feed consumed per 100 lb. gain, lb.					
Cottonseed meal	181	156	153	147	179
Ground sorghum grain	352	305	298	287	347
Prairie hay	735	558	470	376	722
Dehydrated alfalfa leaf meal	...	77	151	219	...
Total—concentrates	533	461	451	435	526
roughage	735	636	622	596	722
feed	1268	1097	1073	1031	1249

[a] 50% steamed bone meal and 50% salt. For group 5 it is shown in text.

Results and Discussion

The average daily gain for all groups was 1.24 lb. (table 1). The average daily gain for the control group (1) was 1.15 lb. while that for the group receiving the control ration plus trace minerals (5) was 1.12 lb. These two lots of steers required practically the same number of pounds of concentrates, roughage and total feed per unit of gain. The final blood carotene levels for these two groups were 55 and 57 mcg. per 100 ml. of blood plasma, respectively (table 2). It is evident that the inclusion of trace minerals did not change the performance of

the cattle noticeably, and these two groups may be considered together as a control group for comparison with the other animals.

Steers in groups 2, 3 and 4, which received 1, 2 and 3 lb. of dehydrated alfalfa leaf meal, respectively, in addition to the basal ration gained an average of 1.31 lb., which was significantly higher than that for the steers not receiving alfalfa leaf meal ($P<0.05$).

TABLE 2. THE EFFECTS OF VARIOUS LEVELS OF DEHYDRATED ALFALFA LEAF MEAL ON THE CONCENTRATION OF CAROTENE IN THE RATION AND IN THE PLASMA OF STEER CALVES FED GROWING RATIONS

Group[a]	1	2	3	4	5
Variables					
Alfalfa leaf meal	0	1 lb.	2 lb.	3 lb.	0
Trace minerals	0	0	0	0	+
Carotene content of ration, mg.[b]	14.7	53.5	105.9	158.9	14.6
Plasma carotene, mcg. per 100 ml.					
Initial[c]	90	90	90	90	90
Final	55	110	144	173	57

[a] Ten steers per group.
[b] Average daily per steer for the entire period.
[c] Average of random sample (10 animals) from all groups.

This was an increase of 15.4% in gain and comparable to data presented by Beeson and Perry. Bentley *et al.* (1952) and Klosterman *et al.* (1953) reported results comparable to these and concluded that poor quality hay was deficient in some of the essentials supplied by alfalfa ash, molasses fermentation solubles or a trace mineral mixture. In this study, digestible protein, calculated net energy and carotene were increased with increasing levels of dehydrated alfalfa leaf meal; therefore the increased gains may be attributed to factors other than minerals present in the dehydrated alfalfa leaf meal.

While feed intake was held constant for all groups, feed per 100 lb. of gain was definitely lower for the steers fed alfalfa meal. The three groups fed alfalfa leaf meal required an average of 1,067 lb. of feed per 100 lb. of gain as compared with 1,259 lb. for the two groups not so fed. This was a decrease of 15.2% in feed requirement per unit of gain. Steers in group 4, which received 3 lb. of dehydrated alfalfa leaf meal, required 23% less feed, 22% less concentrates and 24% less roughage, per 100 lb. gain than steers receiving the basal ration.

Differences in daily gain made by the steers which received 1, 2

and 3 lb. levels of dehydrated alfalfa leaf meal were not statistically significant, but a trend was evident in favor of higher levels of the supplement. Gains of the steers in group 4 were increased 17% above those of steers in groups 1 and 5, while the calculated net energy and protein in this ration were increased 23 and 12%, respectively. These data are in agreement with findings of Beeson and Perry.

When alfalfa leaf meal was added to the rations in this experiment, the plasma carotene content was significantly increased (table 2). Since the daily gains were higher for steers fed these rations, the increased gains could be the result of the increased carotene content as suggested by Bechtel and Ward (1936) and Frey *et al.* (1947), who concluded that rations low in carotene did not produce satisfactory growth. The average blood plasma carotene in steers receiving 1, 2 and 3 lb. levels of dehydrated alfalfa leaf meal was 142 mg. per 100 ml. of plasma as compared to an average of 56 mg. per 100 ml. of plasma for groups 1 and 5, which did not receive the supplement. The average blood carotene of steers receiving 3 lb. of dehydrated alfalfa leaf meal was increased by 90% over their initial level and by 200% over steers in groups 1 and 5 at the close of the experiment. No significant differences were noted in the plasma carotene level in steers receiving various levels of dehydrated alfalfa leaf meal; however a trend again developed which indicated that the plasma carotene was increased with increasing levels of dehydrated alfalfa leaf meal. All steers receiving dehydrated alfalfa leaf meal in the ration had significantly higher levels of carotene in the blood than steers in either group 1 or 5 when the experiment was concluded. Blood carotene levels of steers not receiving dehydrated alfalfa leaf meal had decreased 40% at the close of this test, but those steers did not show symptoms of vitamin A deficiency.

In view of the results obtained in group 5, which received trace minerals and did not differ in any way from the controls, it appears that a greater portion of the increased gains and feed efficiency found in groups receiving dehydrated alfalfa leaf meal was not due to the known mineral content of the ration but was due to increased digestibility, increased carotene, higher levels of energy and protein, or a combination of these factors.

Summary

Dehydrated alfalfa leaf meal and trace minerals were added to a basal growing ration composed of poor quality prairie hay, 2 lb. of cottonseed meal and 4 lb. of ground milo grain.

Levels of 1, 2 and 3 lb. of dehydrated alfalfa leaf meal substituted for hay produced higher daily gains and more efficient gains. The steers which received this supplement gained 15.4% faster and required 15.2% less feed per unit of gain.

Blood plasma carotene levels were increased with increasing levels of dehydrated alfalfa leaf meal. Plasma carotene in the steers receiving 3 lb. of dehydrated alfalfa leaf meal daily had increased 90% above the level at the beginning of the test, and was 200% above the level found in the controls at the close of the experiment. Steers not receiving dehydrated alfalfa leaf meal were unable to maintain their plasma carotene levels which decreased by 40% during this study.

Trace minerals did not change the performance of the steers and were without effect when added to a poor quality prairie hay ration under the conditions of this test.

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THE EFFECT OF CHANGE OF RATION ON THE REQUIRED LENGTH OF PRELIMINARY FEEDING PERIOD IN DIGESTION TRIALS WITH SHEEP

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INHERENT in the problem of arriving at valid apparent digestion coefficients are difficulties of varying magnitude which affect the accuracy of the determined values. It is, therefore, of importance that the influence of the factors responsible for the existing variation in such coefficients be reduced to a minimum.

The effect of length of preliminary feeding period on the accuracy of apparent digestion coefficients has received little experimental attention. The current practice in digestion trials is to allow an arbitrarily determined length of time for feed residues of the previous ration to be eliminated before collection of feces is begun.

In the light of present beliefs as to the activity of bacteria in ruminant digestibility (Gall *et al.* 1949; 1953) and of the factors affecting their activity (Burroughs *et al.* 1948, 1950, 1951), a re-examination of the length of preliminary feeding period required in digestion trials seems warranted. This need is emphasized where an experimental ration is greatly different, physically and chemically, from the previously fed ration. It is conceivable that an adjustment of rumen bacteria, as to kind and number, to a higher "quality" or lower "quality" roughage will be a gradual process, and will require longer than the preliminary feeding periods currently employed for ruminants.

The work reported herein deals with the effect of two ration changes on the length of preliminary feeding period required to obtain reproducible apparent digestion coefficients with sheep.

Experimental Procedure

Four Southdown ewes were transferred directly from pasture to individual metabolism cages. For 70 days immediately following, they were fed field-cured hay (predominantly Timothy). This was the first ration change and constituted Trial A.

Immediately upon completion of Trial A, a second 70-day feeding period started in which the same sheep were fed a ration consisting of

65% roughage similar to that fed in Trial A, plus 35% grain mixture (60% whole oats and 40% wheat bran). This was the second ration change and constituted Trial B. The proximate composition of the rations fed in Trials A and B is given in table 1.

In each trial, the feed intake of each sheep was adjusted to a constant level, slightly below *ad libitum* intake, to eliminate refused feed. The sheep had free access to water and to cobalt-iodized salt at all times.

Beginning on the second day of each trial, and for 70 succeeding days, the total daily fecal output of dry matter was determined for each

TABLE 1. PROXIMATE COMPOSITION OF RATIONS

Ration components	Feeding trial in which used	Proximate composition					
		Dry matter	Crude protein	Crude fiber	Ether extract	N-free extract	Ash
		%	%	%	%	%	%
Hay, 100%	A	91.3	7.7	41.6	1.2	44.7	4.8
Hay, 65% + oats, 21% + bran, 14%	B	90.7	9.8	31.6	2.0	51.9	4.7

sheep. Standard procedures for the determination of the proximate principles were used on ration components and individual daily feces samples in each trial.

The apparent digestion coefficients of the dry matter, crude protein, crude fiber, ether extract and nitrogen-free extract of the rations used in both trials were computed by the conventional "time collection" method. Running averages of the daily dry matter output of each sheep for overlapping successive 10-day periods were calculated in both trials—that is, averages for days 1–10, 2–11, 3–12, etc., were obtained. It was thus possible to calculate apparent digestion coefficients of the various nutrients of the rations used in Trials A and B for preliminary feeding periods ranging from zero to 60 days.

Results and Discussion

The average apparent digestion coefficients for the dry matter, crude protein, crude fiber, ether extract and nitrogen-free extract of the rations fed in Trials A and B are represented graphically in figures 1 and 2, respectively. By using the 10-day collection period normally employed in sheep digestion trials, these coefficients express quantitatively the trends in apparent digestibility of the nutrients studied for preliminary feeding periods of from zero to 60 days following a ration change.

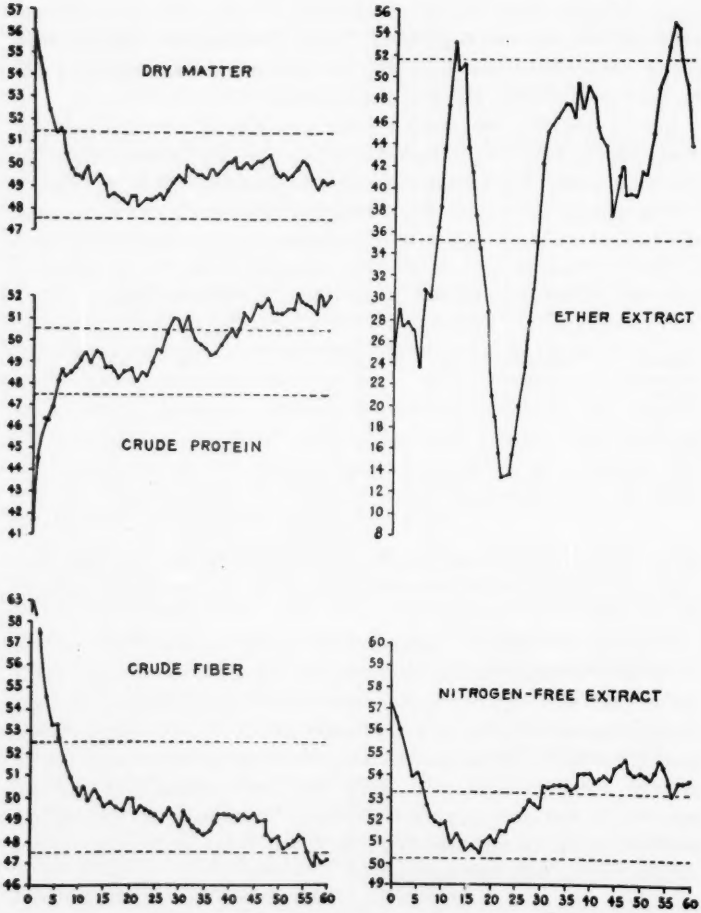

Figure 1. Trends in Apparent Digestibility of Fractions of an All-Roughage Sheep Ration (Trial A). On each graph, apparent digestion coefficients are read from the ordinates and the number of days in the preliminary feeding period from the abscissa. The points are plotted according to the number of days of preliminary feeding which preceded the 10-day collection period. Example:—56% digestibility of dry matter at 0 days means that the 10-day collection was started without any preliminary feeding.

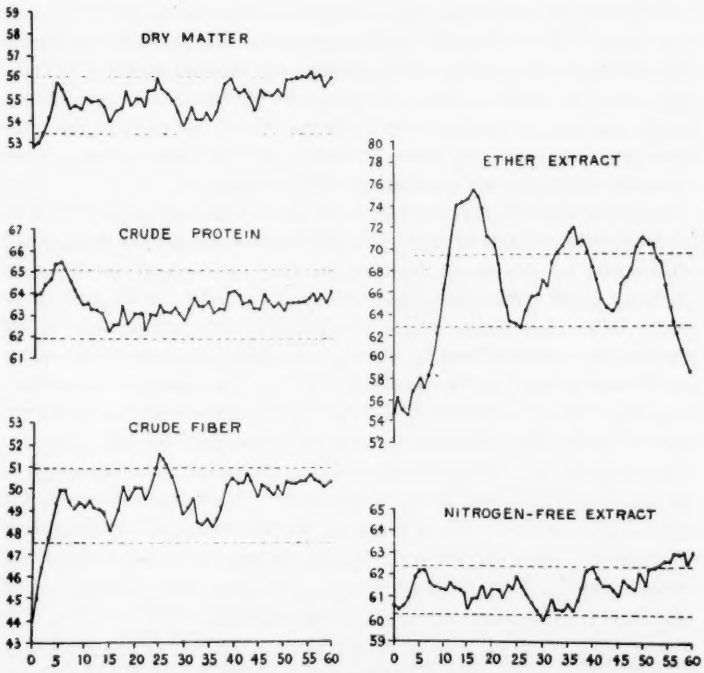

Figure 2. Trends in Apparent Digestibility of Fractions of a Roughage plus Concentrate Sheep Ration (Trial B). On each graph, apparent digestion coefficients are read from the ordinates and the number of days in the preliminary feeding period from the abscissa. The points are plotted according to the number of days of preliminary feeding which preceded the 10-day collection period. Example:—53% digestibility of dry matter at 0 days means that the 10-day collection was started without any preliminary feeding.

The graphs in figures 1 and 2 show that a constant digestibility level for the nutrients studied was not attained in either trial. Instead, following either an initial increase or decrease in apparent digestibility, the characteristic tendency of the coefficients was towards a form of rhythmic fluctuation, being most pronounced in the case of ether extract. Concomitant with these rhythmic fluctuations were minor day-to-day variations, so that for the extended preliminary feeding period of 60 days, short irregular intervals were observed. Dodsworth (1954) reported similar rhythmic trends, but they were not critically examined.

In Trial A, in which the ration change was from pasture to field-cured hay, a similarity was found to exist between the graphs for the apparent digestibility of dry matter and nitrogen-free extract (figure 1). They were found to decrease initially to about the 15-day preliminary feeding period and then to increase slightly to the 30-day period. For the final interval of approximately 30 days, the graphs for these nutrients were somewhat irregular, but showed no definite trend.

Apparent crude fiber digestibility showed a slight but gradual declining trend for the entire 60 days of preliminary feeding period. A plausible explanation for this result rests on the fact that several investigators (Bentley *et al.* 1951; Burroughs *et al.* 1948, 1950, 1951; and Swift *et al.* 1951) have shown certain minerals, notably phosphorus, to be required for cellulose digestion. Since poor quality hay normally provides insufficient amounts of such elements, and since no mineral supplement, except for cobalt-iodized salt, was fed to the sheep, the apparent digestibility of crude fiber may have been steadily depressed for this reason.

As opposed to crude fiber digestibility, the trend in apparent crude protein digestibility was to increase slightly. This result was somewhat surprising particularly with a ruminant species, where the crude protein of the ration is considered to be bound, at least in some measure, by fibrous material, and therefore its apparent digestibility is expected to follow the trend of that for crude fiber digestibility.

The graph for ether extract showed distinct maximum and minimum points of digestibility. The variability range of these coefficients was 41.5 units of percent. Hence, the problem of deciding upon a suitable length of preliminary feeding period when determining the apparent digestibility of ether extract requires considerable attention. The low fat content of the ration may have magnified the variability of the digestion coefficients; however, the practical significance of the results may be minimized for the same reason.

In Trial B, in which the ration change was from all-roughage to roughage (65%) plus concentrate (35%), the effect of extending the length of preliminary feeding period upon dry matter, crude fiber and nitrogen-free extract digestibility by sheep yielded similar types of graphs (figure 2). With all these nutrients, maximum points occurred after approximately 5, 25, and 40 days of preliminary feeding. Minimum points occurred approximately after 15 and 30 days.

Crude protein exhibited a sole maximum point of apparent digestibility after a 6-day preliminary feeding period. Thereafter, a decrease was

noted to the 15-day mark, and from then to the end of the feeding period, the trend of the graph was to level off.

Ether extract digestibility reached definite maximum peaks at the end of the 16, 36, and 51 days of preliminary feeding, while equally definite minimum points were obtained after preliminary feeding periods of 26, 44 and 60 days. The variability range of these coefficients was large, but not to the degree observed for the ether extract in Trial A. This may have been due, at least in part, to the fact that the ration fed in Trial B contained nearly twice the amount of ether extract found in the all-roughage ration.

An analysis of variance was carried out on the individual apparent digestion coefficients for each nutrient studied in Trials A and B. From these data, the least significant difference between the means of the coefficients for the various lengths of preliminary feeding periods of from zero to 60 days was calculated for each nutrient. Using the average apparent digestion coefficient calculated after 10 days of preliminary feeding as the standard value against which all succeeding average digestion coefficients were tested for significant differences, a range of apparent digestibility was calculated for each nutrient to include values which did not differ significantly from the "standard". The limits of this normal range of variability for each nutrient are shown in figures 1 and 2 by the two horizontal dotted lines on the graphs.

The use of this procedure was justified in that the immediate problem was concerned with whether or not the normally employed 10-day preliminary feeding period was of sufficient duration for the apparent digestion coefficients of the nutrients studied to become constant following a ration change.

It was expected that at least some of the apparent digestion coefficients of the various nutrients would fall outside their normal ranges as defined above, particularly in the initial stages of the changes of ration. This expectation was confirmed.

In Trial A (figure 1), in the case of dry matter, and in Trial B (figure 2), in the case of dry matter, crude protein and crude fiber, there was evidence that the variation in the apparent digestion coefficients following the 10-day preliminary feeding period was the result of chance, since all, or the majority, of the coefficients thus included fell within the normal ranges. Insofar as the remaining nutrients in each trial were concerned, it was apparent that causes other than chance variation were responsible for certain coefficients falling outside the normal range following the 10-day preliminary feeding period.

It should be noted here that, except for ether extract digestion coefficients, the normal range of the coefficients for the remaining nutrients was small, being of the order of 3 to 5 units of percent in Trial A and not exceeding 3.5 units of percent in Trial B. It is of significance that these values are not beyond the range of variability of apparent digestion coefficients normally observed when groups of animals of this species are treated alike.

In brief, constant digestion coefficients were not obtained for certain nutrients even when the length of preliminary feeding period was extended to 60 days, and any increase in precision thereby realized was insignificant in practice. For these reasons, there appears to be little justification for increasing the length of preliminary feeding period in sheep digestion trials beyond 10 days.

Summary

Four sheep were fed a field-cured all-roughage ration immediately upon their removal from pasture, and a hay plus grain ration immediately following the all-roughage ration. By extending the length of preliminary feeding period it was found that the apparent digestibility of the dry matter, crude protein, crude fiber, ether extract and nitrogen-free extract of both rations showed rhythmic fluctuations.

Because of these fluctuations, it seemed highly improbable that constant and maximum digestibility of the nutrients studied is biologically normal.

A statistical analysis of the individual apparent digestion coefficients of each of the nutrients calculated for preliminary feeding periods of from zero to 60 days indicated that following the "standard" 10-day preliminary feeding period, and with the exception of ether extract, the effect of time on the variation of these digestion coefficients was of minor significance.

Since constant digestion coefficients were not obtained for certain nutrients even when the length of preliminary feeding period was extended to 60 days, and since any increase in precision thereby realized was shown to be insignificant in practice, there does not appear to be any justification for increasing the length of preliminary feeding period in sheep digestion trials beyond 10 days.

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THE AMOUNTS OF SHORT CHAIN ACIDS FORMED DURING RUMEN FERMENTATION [1]

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RUMINANTS have long been known for their ability to utilize roughage. The advent of intensive animal production and increased concentrate feeding, having fostered anomalies in rumen fermentation. These include changes in the production of short chain acids which are a major source of energy for the cow as well as an end product of the fermentation. Information concerning amounts and types of these acids formed in the rumen is imperative to a better understanding of feed utilization. This study was undertaken to determine the quantity of short chain acids made available to the ruminant through fermentation of the roughage and concentrate in the ration. The turnover curve method used in this study is an application of the general method described by Solomon (1953).

Experimental

Twin Holstein cows, T1 and T2, weighing 1050 and 1110 lb. and a Guernsey steer, C707, were used in this experiment. The steer weighed 1420 lb. when used for the restricted roughage trial and 1500 lb. for the all hay trial. All three animals were fitted with fistula plugs described by Hentschl *et al.* (1954). T1 was in the second month of lactation and T2 was dry.

The experimental rations were fed twice daily at 8 a.m. and 3 p.m. for at least three weeks before each trial. Alfalfa hay was used for the roughage. The concentrate mixture contained 77% ground corn, 20% soybean oil meal, 1% Ca_2HPO_4, 1% NaCl, 1% $CaCO_3$ plus vitamin A and irradiated yeast. For the restricted roughage trials, T1 received a ration of 28 lb. of concentrate plus 4 lb. of hay and C707 received 10 lb. of concentrate plus 4 lb. of hay. For the all hay trials, T2 received a ration of 30 lb. of hay and C707 received 24 lb. of hay.

On the days of the four trials, feeding was restricted to 2 hours in the morning for the all hay ration and ¾ hour for the high concentrate-

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restricted roughage ration. Water was permitted at will during the next 24 hours. During the feeding period, T1 ate 11 lb. of concentrate and 2 lb. of hay, T2 ate 8 lb. of hay, C707 ate 5 lb. of concentrate and 2 lb. of hay for the restricted roughage trial and 6 lb. of hay for the all hay trial.

The time half way between initiation and termination of feeding was taken as 0 hour for purposes of later sampling and computation. However, in order to avoid disturbing the animal while eating, the sample recorded as 0 hour was taken just prior to feeding. Ten to 11 samples of the liquid in the middle part of the ventral sac in the rumen were taken at intervals up to 24 hours after 0 hour and strained through cheesecloth into a volumetric flask containing 50% sulfuric acid equal to 3% of its volume. This volume of sulfuric acid lowered the pH to 1.5 to 2.0 and yielded a final sample containing about 91.3% rumen liquid on a dry matter free basis. Most of the suspended solids in the initial sample were precipitated by the sulfuric acid. These samples were stored at 6° C. until analyzed.

Cheese-cloth strained rumen liquid from T1 and T2 were used for inocula for the *in vitro* fermentations which were conducted in 1 litter Erlenmeyer flasks in a 39° C. water bath. Four flasks were pre-flushed with CO_2 and placed in the bath within 20 minutes after removal of the inocula from the cows. Two of the flasks contained 600 gm. of inocula from the hay fed cow. An estimated 12 gm. of total digestible nutrients (T.D.N.) as alfalfa leaf meal served as substrate in one of the flasks and an estimated 12 gm. of T.D.N. from the concentrate mix served as substrate in the other. The other 2 flasks were similarly prepared using 600 gm. of inocula from the concentrate fed cow. The flasks were kept stoppered except when removing samples with a pipette at the beginning of the fermentation and at 4 intervals between 40 and 140 minutes thereafter.

Acetic, propionic, and butyric acids were determined by direct chromatography of rumen liquid on silica gel as described by Harper (1953) with modifications. Thirteen gm. of dry silicic acid and 7.5 ml. of 1.6M potassium phosphate pH 6.3 buffer were used for the buffered section. A 38 mm. diameter column was used. The sulfuric acid section of Harper (1953) was omitted since it had no effect on the results of this experiment. The sample section was prepared by weighing 6 to 7 gm. of rumen liquid directly on to 10 gm. of dry silicic acid on a watch glass. The silicic acid and sample were then quantitatively transferred to a mortar and thoroughly mixed. Fifty ml. of chloroform was

used to form a slurry and used as a vehicle to transfer this section to the column. Eluate fractions of appropriate size as determined by preliminary trials were collected starting immediately after adding the sample section. The flow rate was about 150 ml. per hour. Four columns were run simultaneously. Further additions of solvent were made using a separatory funnel adjusted to keep 5 to 10 ml. of solvent covering the column. A 50 ml. addition of pure chloroform was followed by 50 ml. portions of 1, 2.5, 5, 10 and 20% n-butanol in chloroform solutions. Additional 20% n-butanol in chloroform was used to give a total eluate volume of 500 ml. Blank determinations were made with each batch of reagents and appropriate corrections made.

The chromatographic procedure was tested with pure acids alone, and added to rumen liquid. Recovery in 4 trials with 0.5 to 3.8 millimoles of added acetic acid was 93% with a standard deviation of 8%. Recovery of 0.2 to 0.5 millimoles of butyric acid was similarly $96 \pm 6\%$. Threshold volumes for butyric, propionic, and acetic acids were about 70, 200, and 280 ml., but varied somewhat with changes in reagents and the amount of short chain acid applied to the column. The values reported as butyric acid include traces of higher acids. For analysis of the volatile acids produced *in vitro,* the method of Keeney (1955) was used with slight modification. Results from the two methods were in good agreement.

Results and Discussion

Figure 1 portrays the regression of the concentrations of acetic, propionic, and butyric acids in the rumen on time after feeding. Table 1 lists the amounts of acetic, propionic, and butyric acids produced from each lb. of T.D.N. ingested. It was assumed for computational purposes that the hay contained 50% T.D.N. and the concentrate 75%.

The values recorded in table 1 were derived from the regression equations portrayed in figure 1 whereby the concentrations of these acids in the rumen were adjusted for: (a) disappearance from the rumen with time after feeding; (b) the portion of the potential concentration of these acids which remained to be produced with time after feeding; (c) the residual concentration of these acids remaining from previous feedings. An example of these calculations is shown in figure 2. The rates at which the acids disappeared from the rumen are listed in table 2.

The natural logarithms of the acetic acid concentrations from 3 hours after feeding, and of the propionic and butyric acid concentrations from 3.5 hours after feeding, through the fasting period were fitted to a regression on time by the method of least squares as described by

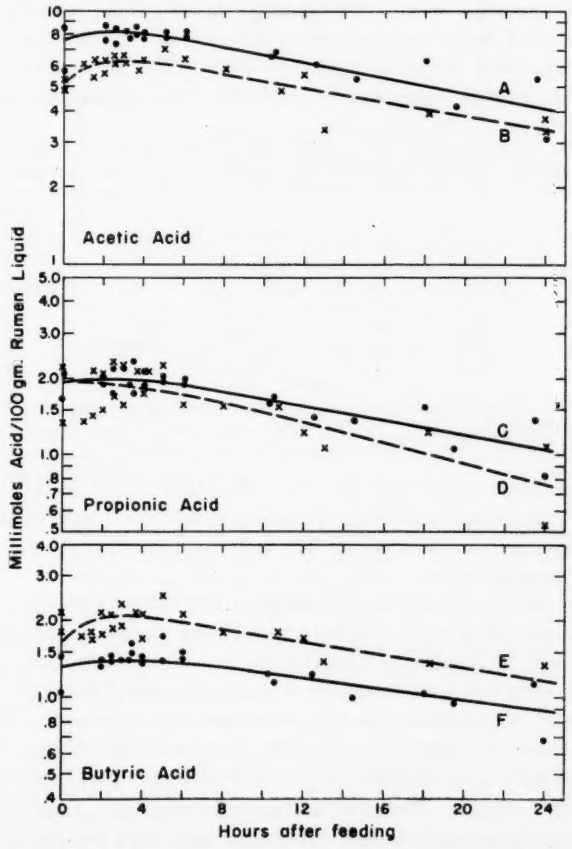

Figure 1. The concentration of short chain acids in the rumen.
Hay ration ———— **Concentrate ration** — — — —

The equations for the curves are:

A. $A_t = 9.59e^{-0.0353t} - 1.90e^{-0.523t}$.
B. $7.16e^{-0.0311t} - 2.16e^{-0.838t}$.
C. $2.28e^{-0.0222t} - 0.36e^{-0.450t}$.
D. $2.36e^{-0.0465t} - 0.41e^{-0.276t}$.
E. $2.35e^{-0.0284t} - 0.73e^{-0.728t}$.
F. $1.63e^{-0.0948t} - 0.32e^{-0.851t}$.

Snedecor (1946). Any production of these acids subsequent to 3 or 3.5 hours after feeding would result in deviations from their logarithmic disappearance. The small magnitude of the standard errors reported in table 2 largely precludes the possibility.

The 0 hour extrapolation of this regression is the natural logarithm of A_0 and the slope is k_1. The concentration of acetic, propionic, and butyric acids determined between 0 and 3 or 3.5 hours after feeding were subtracted from the A_0 value adjusted for time after feeding according to the disappearance regression. The natural logarithms of

TABLE 1. THE AMOUNT OF ACETIC, PROPIONIC, AND BUTYRIC ACIDS PRODUCED FROM ONE POUND OF TOTAL DIGESTIBLE NUTRIENTS

	All hay ration		Restricted roughage —concentrate ration		Pooled data from both rations
Acid	mM/100 gm.[a]	%	mM/100 gm.[a]	%	mM/100 gm.[b]
Acetic	0.52	68.4	0.30	65.2	.24–.67
Propionic	0.15	19.7	0.06	13.0	.02–.26
Butyric	0.09	11.8	0.10	21.7	.04–.21
Total	0.76	....	0.46	....	.....

[a] Millimoles of acid per 100 gm. of rumen liquid.
[b] Range at 95% confidence level.

these differences were fitted to a regression against time as before. The slope of this second regression equation is k_2 and the 0 hour extrapolate is the natural logarithm of A_p. The tests for significance were carried out on the logarithms.

There were no significant differences at the 5% level between any of the disappearance rates. However, the pooled disappearance rates for acetic acid approached a significantly faster rate than that for the butyric acid. This is in agreement with Pfander and Phillipson (1953). The rates of production of the acids were not significantly different in any case and ranged from 28 to 84% per hour. The amounts of each acid produced from a pound of T.D.N. from each ration were not significantly different. However, acetic acid production from hay approached significantly greater value than that from the high concentrate ration. The molar ratio of acetic to propionic acid was reduced by the high concentrate ration but, the reduction was not as marked as that reported by Tyznik (1951).

The initial concentration of acetic and propionic acids in the *in vitro* fermentations were subtracted from the concentration of these acids

present after incubation for 40 to 140 minutes. These values, presented in table 3, represent the acid produced during this time with the different treatments. Since the fermentations were not complete these

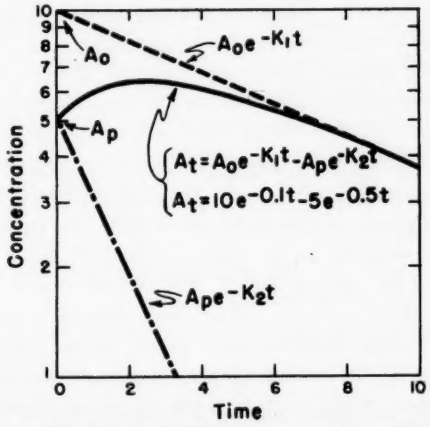

Figure 2. A graphic portrayal of the turnover curve analysis; — — — disappearance of product from the rumen; — — — — conversion of feed to product; ———— concentration of product in the rumen resulting from combination of the other two curves.

Where, $A_t = A_o e^{-k_1 t} - A_p e^{-k_2 t}$

A_t=the concentration of the acid in mM per 100 gm. of rumen liquid.

A_o=the disappearance regression extrapolated to 0 time; this could represent the amount of acid which would be present if the fermentation were completed without any disappearance of the acid;

$A_p = (A - A_t)$ when t is 0; this should represent the amount of acid produced from the current feeding in mM/100 gm. of rumen liquid;

e=base of the natural system of logarithms (2.71828);

k_1=rate of disappearance of the acid from the rumen; 100 k_1=%/hour of disappearance of the acid present at any given time;

k_2=rate of acid production of rate of conversion of fermentable feed into its acid product;

t=time after feeding in hours.

values are not representative of the total amount of the acid which could be formed from the substrate. More acetic acid was produced from the hay substrate than from the concentrate substrate regardless of inocula ($P<0.01$). More propionic acid was produced with inocula from the concentrate fed cow than with inocula from the hay fed cow

TABLE 2. THE DISAPPEARANCE RATES FOR ACETIC, PROPIONIC, AND BUTYRIC ACIDS FROM THE RUMEN

	All hay ration		Restricted roughage ration		Pooled data from both rations	
Acid	% per hr.	S.E.[a]	% per hr.	S.E.[a]	% per hr.	S.E.[a]
Acetic	3.5	0.4	3.1	0.5	3.3	0.3
Propionic	3.2	0.5	4.6	0.9	...	...
Butyric	2.5	0.5	2.8	0.5	2.7	0.3

[a] Standard error.

regardless of the substrate being fermented ($P<.01$). This suggests that the rations themselves control the production of acetic acid while the amount of propionic acid produced is controlled by the microbiota.

The energy supplied to the cow by the short chain acids can be computed from the data in table 2. The average animal in the *in vivo* experiment weighed 1270 lb. Carroll and Hungate (1954) concluded that rumen contents constitute 14% of the bovine body weight. The average weight of the rumen contents in this experiment would then be 178 lb. which would contain about 70 kg. of rumen liquid (dry matter free). Computing from the 95% confidence level ranges given in table 1, a lb. of T.D.N. yields 168 to 469 mM. of acetic acid, 14 to 182 mM. propionic acid, and 28 to 147 mM. butyric acid. Converting

TABLE 3. THE FORMATION OF ACETIC AND PROPIONIC ACIDS BY RUMEN MICROBIOTA *IN VITRO*

	Mean production of acids Millimoles of acid per 100 gm. fermentation liquid	
Treatment	Acetic acid	Propionic acid
Hay inoculum-hay substrate	2.15 (0.21)[a]	1.06 (0.07)
Hay inoculum-grain substrate	0.96 (0.40)	0.22 (0.06)
Hay inoculum-mean	1.55 (0.30)[b]	0.64 (0.16)
Grain inoculum-hay substrate	3.35 (0.26)	2.90 (0.25)
Grain inoculum-grain substrate	1.69 (0.20)	2.37 (0.27)
Grain inoculum-mean	2.52 (0.35)	2.64 (0.19)
Difference due to inocula:	0.964[c]	2.00**
Hay substrate-mean	2.75 (0.28)	1.98 (0.37)
Grain substrate-mean	1.33 (0.25)	1.30 (0.43)
Difference due to substrate:	1.42**	0.68

[a] Mean of four samples of fermentation liquid taken after 40 to 140 minutes incubation; the standard deviation of the mean is shown in parentheses.
[b] Mean of eight samples; the standard deviation of the mean is shown in parentheses.
[c] Approaches significance at the 5% level.
** Significant at the 1% level.

the values to kcal., a total energy of 55.0 to 232.3 kcal. per lb. of T.D.N. is obtained, 35.2 to 98.3 are represented by acetic acid, 5.1 to 66.9 by propionic acid, and 14.7 to 77.1 by butyric acid. If one lb. of T.D.N. is equivalent to 1814 Cal. (Brody, 1945), the cow obtains 3 to 13% of its energy from short chain acids.

A constant rumen volume was assumed in computing these regression equations. The data of Chance *et al.* (1953) support this assumption. Irregular fluctuations in volume would increase the standard error and hence, be corrected for by the range in the 3 to 13% estimate. However, if rumen volume increases appreciably and regularly after eating due to salivation, drinking, or influx of water from the tissues, these estimates would be too low. Similarly, if rumen volume decreases appreciably with fasting, as suggested by the data of Weller and Gray (1954), both the disappearance rates and the energy estimates are biased downwards. If a method for determination of rumen volume at frequent intervals were available, the accuracy of these estimates would be greatly enhanced.

The carbon balance studies of McNaught (1951) and of Heald (1952) indicate a 25 to 50% conversion of feed energy to short chain acid energy. Carroll and Hungate (1954) estimate that short chain acids account for 66% of the available feed energy while Pfander and Phillipson (1953) imply a similar value.

Summary

The concentration of acetic, propionic, and butyric acids in 3 bovine rumens was determined at various times after feeding either an all hay ration or one consisting largely of concentrates. Two trials were conducted on each ration. The concentration of each acid first increased and then decreased with time after feeding. The values obtained were fitted to turnover curves. Acetic acid disappeared from the rumen at the rate of 3.3% per hour and butyric acid at the rate of 2.7% per hour. The standard error was 0.3%. The disappearance rate of propionic acid on the high concentrate ration was 4.6% per hour versus 3.2% per hour on the hay ration. The rates for conversion of feed to short chain acids ranged from 28 to 84% per hour.

Pooling data from the 4 trials, the mM of acids per 100 gm. of rumen liquid which were produced from 1 lb. of T.D.N. were, 0.24 to 0.67 acetic, 0.02 to 0.26 propionic, and 0.04 to 0.21 butyric (P .05). The average rumen in these trials was estimated to contain 70 kg. of liquid.

Using these values, it was computed that the cow obtains 3 to 13% of its energy from short chain acids.

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THE EFFECT OF HIGH LEVELS OF COBALT ON THE *IN VITRO* DIGESTION OF CELLULOSE BY RUMEN MICROORGANISMS [1]

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ALTHOUGH it has been shown that cobalt is required by the ruminant for the synthesis of vitamin B_{12} in the rumen, the effect of cobalt on the digestion of cellulose is not clear. The work of Gall *et al.* (1949) suggests that the number and effectiveness of the fiber-digesting bacteria of the rumen of the sheep are decreased when a cobalt-deficient ration is fed. On the other hand, Becker and Smith (1951) found that lambs fed a cobalt-deficient ration showed significantly higher coefficients of digestibility for crude fiber than did lambs receiving adequate cobalt. The depressed feed intake of the cobalt-deficient lambs probably contributed to their more efficient digestion of crude fiber.

According to Stewart (1953), cobalt deficiency restricts the appetite of lambs and it is this restricted appetite which is the cause of the clinical syndrome. The work of Clark and Quin (1951) indicates, in some cases at least, that increased appetite, as reflected by increased intake, may be the result of more rapid digestion of cellulose resulting in more rapid passage. Bowstead and Frideen (1948) found that 0.5 gm. of cobalt per day restored the appetites of some urea-fed cows that had suddenly gone off feed. Other cows showed limited improvement after cobalt feeding.

The experiments presented here were initiated to determine whether the addition of cobalt or vitamin B_{12} in excess of the amounts normally present in the rumen had a stimulatory effect upon cellulose digestion.

Experimental

The inocula for the laboratory fermentation of cellulose were obtained from a fistulated Holstein steer receiving a ration of timothy hay.

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Samples of the fluid portion of the ingesta were strained through a single layer of cheesecloth to remove the larger plant particles. The fermentation procedure used was a modification of the method described by Huhtanen *et al.* (1954). The substrates were Solka-Floc,[5] cotton linters which had been extracted with a mixture of benzene and alcohol (1:2), alfalfa leaf meal,[6] and timothy hay. The substrate was weighed into a 950 ml. brown glass reagent bottle and 800 ml. of rumen fluid was added. The amount of substrate used was calculated to give

TABLE 1. SALT SOLUTION USED FOR *IN VITRO* FERMENTATIONS

Salt	Concentration
	gm./L.
$NaHCO_3$	4.9
$Na_2HPO_4 \cdot 12H_2O$	4.7
NaCl	0.24
KCl	0.29
$CaCl_2 \cdot 2H_2O$	0.026
$MgCl_2 \cdot 6H_2O$	0.064
$FeSo_4 \cdot 7H_2O$	0.04
$ZnSO_4 \cdot 7H_2O$	0.002
$CuSO_4 \cdot 5H_2O$	0.001
$MnSO_4 \cdot H_2O$	0.001

a cellulose concentration of approximately 1%. The temperature of the mixture was maintained by placing the bottle in a water bath at 39° C. Carbon dioxide was bubbled through the mixture fast enough to give efficient mixing, the bottle was swirled viogorously, and 25 ml. of the suspension was pipetted rapidly into a cellophane sac [7] by means of a pipette with a large orifice. The sac was then placed in a 4-oz., screw-capped bottle containing 100 ml. of salt solution (table 1) which had previously been warmed to 39° C. and gassed with carbon dioxide. When cobalt or vitamin B_{12} was used, it was added to the fluid in the sac and to the salt solution; when urea was used it was added only to the inoculum. The incubation period was either 18 or 24 hours. Replicate 25 ml. samples were pipetted into beakers at the time the incubated samples were inoculated. These were used to determine the actual amount of cellulose present at the start of the incubation.

The following modification of the Crampton and Maynard (1938) method was used for the determination of cellulose. After incubation,

[5] Solka-Floc BW–40, Brown Co., Berlin, N. H.
[6] Lot No. 28–3MA–131, Cerophyl Laboratories Inc., 2438 Broadway, Kansas City 10, Mo.
[7] Made from cellophane tubing 32/32, Visking Corp., Chicago. Ill.

the contents of the sac were transferred to a 150 ml. beaker and dried at 105° C. The reagents were added to the beaker and the mixture was refluxed on a hot plate. A round-bottom flask filled with cold water served as a condenser. Selas porcelain crucibles of XF porosity were used for filtration and ashing, and the benzene and ether washes were omitted.

In the experiments in which cobalt was fed to the animal, the appropriate amount of cobalt sulfate solution was added to the rumen through the fistula at each feeding. A control experiment was carried out with a sample of rumen fluid obtained from the steer on June 3, before cobalt feeding had begun. A second sample was obtained on July 14 after the steer had received 2.5 gm. of cobalt per day for 8 days, 5 gm. per day for 21 days and 7 gm. per day for 9 days. Another sample was obtained on July 19 after the steer had received 7 gm. of cobalt per day for an additional 5 days. The 7 gm. level was continued until July 24 when the level of cobalt fed was increased to 10 gm. daily. A final rumen sample was taken on July 31.

Results and Discussion

Table 2 shows the percentage of cellulose digested when 1 to 200 ppm. of cobalt were added to the *in vitro* fermentation. Under these conditions, 12 ppm. of cobalt caused some depression of cellulose digestion and 100 ppm. caused a very pronounced depression. These results are in agreement with those of McNaught, Owen and Smith (1950) who found that 10 ppm. of cobalt caused a reduction in the amount of protein synthesis by rumen microorganisms *in vitro*. They reported also that some synthesis occurred in the presence of 100 ppm. of cobalt, but that no protein was synthesized in the presence of 1000 ppm. of cobalt.

Added vitamin B_{12} had no appreciable affect on the amount of cellulose digested *in vitro,* even at a concentration of 50 mcg. per ml. (table 3). The amounts of the vitamin used were above the physiological levels since the object of this experiment was to determine whether a stimulation of "normal" cellulose digestion could be obtained. Ruf *et al.* (1953), using a technic designed to dilute out the nutrients added with the inoculum, found no stimulation from the addition of 0.01 mcg. of vitamin B_{12} per ml.

In the above experiments, the cobalt or vitamin B_{12} was added to the *in vitro* fermentations. The possibility remained that cellulose di-

TABLE 2. EFFECT OF COBALT ON THE *IN VITRO* DIGESTION OF THE CELLULOSE IN SOLKA-FLOC [a]

Cobalt added	Cellulose digested
p.p.m.	%
1	57.1
2	53.8
12	46.8
25	40.8
100	18.4
200	8.7

[a] Substrate—1% Solka-Floc.
Non-protein nitrogen—0.1% urea added to inoculum.
Incubation—39° C. for 18 hr.
Cobalt added as $CoCl_2 \cdot 6H_2O$.

gestion might be modified if the cobalt were fed to the animal. Accordingly, cobalt was fed to the steer as described above, and samples of rumen fluid were obtained to determine the ability of the rumen microorganisms to digest the cellulose in a number of substrates, with and without added urea. The results are shown in table 4.

In the presence of urea, the *in vitro* digestion of cellulose was decreased by the feeding of cobalt, except when alfalfa leaf meal was used as the substrate. When urea was not added to the *in vitro* fermentations, a greater decrease in cellulose digestion was obtained, and at the highest levels of cobalt feeding the digestion of the cellulose in alfalfa leaf meal was decreased. In the experiments where urea was added, the sustained ability of the microorganisms to digest the cellulose of alfalfa leaf meal may be associated with the high protein content of the meal. Assuming that the conditions within the rumen and in the laboratory fermentations would permit the cobalt to complex with protein, one possible explanation of the sustained level of digestion of

TABLE 3. EFFECT OF VITAMIN B_{12} ON THE *IN VITRO* DIGESTION OF THE CELLULOSE IN SOLKA-FLOC [a]

Vitamin B_{12} added	Cellulose digested
mcg. per ml.	%
50.	56.6
5.	63.4
0.5	58.3
0.05	59.2
None	60.7

[a] Substrate—1% Solka-Floc.
Non-protein nitrogen—0.1% urea added to inoculum.
Incubation—39° C. for 18 hr.

alfalfa leaf meal cellulose could be that the combined amounts of protein and urea present with the other substrates were insufficient to provide for both complex formation with cobalt and nitrogen utilization by the microorganisms. The lower cellulose digestion, when urea was not added, would be in harmony with this view.

From calculations based on the amounts of cobalt fed and the weight of the total rumen contents on July 20 and 21, a rough approximation of the concentration of added cobalt in the rumen would be 13 ppm

TABLE 4. EFFECT OF FEEDING HIGH LEVELS OF COBALT ON THE *IN VITRO* DIGESTION OF THE CELLULOSE IN VARIOUS SUBSTRATES [a]

	Cellulose digested				
	Urea added			Urea omitted	
Sample taken:	June 3	July 19	July 31	July 14	July 31
	%	%	%	%	%
Solka-Floc	86.3	81.8	69.9	57.3	46.8
Extracted cotton linters	53.1	41.9	....	45.8	....
Alfalfa leaf meal	50.1	51.2	51.1	54.0	44.3
Timothy hay	29.1	22.6	21.5	26.4	14.8

[a] Incubation—39° C. for 24 hr.

when 2.5 gm. of cobalt were fed daily, 25 ppm. when 5 gm. were fed, 35 ppm. when 7 gm. were fed, and 50 ppm. when 10 gm. were fed. These calculations do not take into account the decrease in the amount of fill over the experimental period, the loss due to passage, or the concentration of cobalt in the microorganisms which would probably permit some accumulation of cobalt in the rumen. Comparison of these calculated concentrations of cobalt in the rumen with the amounts added in the laboratory experiments (table 2) suggests that even the lower levels added to the rumen were sufficient to cause some depression of cellulose digestion. This view is strengthened by the fact that the steer lost weight during the experiment. On June 6, the steer weighed 1685 lb., 1598 lb. on July 13, 1523 lb. on July 26, and 1385 lb. on August 9. Part of the loss in weight reflected a decrease in the amount of fill.

The lowest amount of cobalt fed (2.5 gm. per day) was equivalent to 1.5 mg. of cobalt per lb. of body weight. Ward (1951) was able to feed 0.75 mg. per lb. of body weight per day for 84 days to yearling heifers without depressing the rate of gain.

Summary

Cellulose digestion by rumen microorganisms *in vitro* was slightly depressed by 12 ppm. of added cobalt and strongly depressed by 100 ppm. Added vitamin B_{12} up to 50 mcg. per ml. had no appreciable effect on cellulose digestion *in vitro*.

Feeding high levels of cobalt to a steer eventually resulted in a depression of the *in vitro* digestion of cellulose by inocula obtained from this animal. The depression was not as great when urea was added to the *in vitro* fermentation as when it was omitted. Digestion of the cellulose of alfalfa leaf meal in the presence of urea was not depressed.

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PRODUCING LEANER MARKET HOGS BY DIFFERENT FEED COMBINATIONS AND CONTROLLED CORN INTAKE [1]

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INCREASING consumer demand for pork meats with more lean and less fat, and a declining market for lard, have caused much interest in meat-type market hogs. Experiments conducted in England, Canada and the United States (Ashton, 1950; Crampton *et al.*, 1954a, 1954b; Cummings and Winters, 1951; Ellis and Zeller, 1931, 1934; Henry, 1887, 1888, 1889, 1890; Hutchinson, 1953; McMeekan, 1940a, 1940b, 1940c; McMeekan and Hammond, 1939, 1940; Merkel *et al.*, 1953; Robison *et al.*, 1952; Sanborn, 1884, 1885, 1886; Shelton and Cottrell, 1889; Whatley *et al.*, 1951; Winters *et al.*, 1949; Woodman and Evans, 1947) indicate that the type of ration fed to market hogs can be used as a means of increasing the proportion of lean meat in their carcasses. There is general agreement that restricted feed (i.e. total digestible nutrient) intake, particularly during the fattening period, will result in reduced fat deposition. This may be accomplished either by actually reducing the amount of a ration fed daily or by using some type of "filler" to dilute the ration. Studies by Crampton *et al.* (1940) have shown that corn, though equal to barley in feeding value, produced a less desirable lean-fat pattern in hog carcasses.

With these facts in view, this research was initiated. The basic objectives were: (1) to determine diets and methods of feeding hogs which would produce statisfactory growth rates, efficient feed utilization, and carcasses with less fat and more muscle tissue; (2) to correlate economy of production with the production of leaner hog carcasses of acceptable quality; and (3) to determine an easy yet accurate method of estimating the leanness of hog carcasses.

Experimental

This study consists of four pasture trials. The pigs used were purebred Durocs from the Station herd. Pasture was a mixture of ladino clover and alfalfa, and was clipped as necessary to provide a succulent growth at all times. Automatic waterers were provided in each lot. The feeding

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plan is described for each experiment. The pigs were weighed at the beginning and end of each experiment and at 14-day intervals. Pigs were randomly allotted, keeping sex distribution equal and initial weight as uniform as possible. Each pig was fed to a slaughter weight of 215 to 230 lb.

Data were analyzed statistically, both in the feeding trials and the carcass studies, by analysis of variance (Snedecor, 1946).

Feeding Trials

Experiment 1. Five lots of 12 pigs per lot (6 barrows and 6 gilts) were fed on pasture. The average initial weight was approximately 47 lb. With exceptions noted later, the treatments were as follows: Lot 1—High energy (shelled corn, protein supplement, mineral mixture, and salt self-fed, free choice). Lot 2—High energy, followed by medium energy (shelled corn, protein supplement, mineral mixture, and salt self-fed, free choice, to an average weight of 125 lb.; then crimped oats was substituted for the shelled corn). Lot 3—Medium energy (crimped oats, protein supplement, mineral mixture, and salt self-fed, free choice). Lot 4—High energy, followed by low energy (shelled corn, protein supplement, mineral mixture, and salt self-fed, free choice, to an average weight of 125 lb.; then the grain was omitted and protein supplement limited to 0.75 lb. hand-fed per pig daily). Lot 5—Low energy (limited protein supplement hand-fed at the rate of 0.75 lb. per pig daily, mineral mixture and salt self-fed, free choice).

The protein supplement fed in all lots was Purdue Supplement C fortified with a vitamin B_{12}-antibiotic supplement (table 1). Iodized salt was used.

Experiment 2. Four lots of 10 barrows each were hand-fed limited amounts of shelled corn on pasture. The average initial weight was approximately 54 lb. No protein supplement was fed during the experiment but mineral mixture and iodized salt were given free choice. The levels of corn consumed were 100% (self-fed); and 90%, 72% and 53% of the consumption of the self-fed lot. Pasture area increased from one-half to two acres, as the corn allowance decreased.

Experiment 3. The purpose of the third trial was to expand the work done by hand-feeding various levels of corn in Experiment 2. Six lots, 12 barrows per lot, were fed on Ladino clover-alfalfa pasture. Pigs in each lot averaged approximately 50 lb. at the start of the trial. The levels of corn hand-fed were 80, 70, 60, 50 and 40% of the corn the pigs in the

self-fed control lot ate at the same weight. Pigs in the limited-intake lots were hand-fed twice daily half the indicated percentages of a full feed. No protein supplement was fed but mineral mixture and iodized salt were fed free choice. Pasture area varied from one to two acres per lot, increasing as the amount of corn fed was decreased.

TABLE 1. SUPPLEMENT AND MINERAL FORMULAS

	lb.
Protein supplement (Experiment 1)	
Purdue supplement C	98
Aurofac[a]	2
	100
Purdue supplement C	
Soybean oil meal	40
Meat and bone scraps	20
Fish meal	20
Cottonseed meal	10
Linseed meal	10
	100
Mineral mixture (Experiments 1, 2, and 3)	
Pulverized limestone	40
Steamed bone meal	40
Iodized salt	20
	100

[a] Aurofac (Lederle's) contains: 1.8 gm. chlortetracycline
1.8 mg. vitamin B_{12} per lb.

Experiment 4. This experiment was an attempt to reduce corn intake by adding a mineral mixture to ground shelled corn, self-fed, at levels ranging from 3 to 15%. Six lots of 12 pigs each (6 barrows and 6 gilts) were fed in each pasture lot and were started at a weight of 48 lb. The following rations were fed on a free-choice basis: Lot 1—Ground corn and mineral mixture fed separately. Lot 2—Corn 97%, mineral mixture 3%. Lot 3—Corn 94%, mineral mixture 6%. Lot 4—Corn 91%, mineral mixture 9%. Lot 5—Corn 88%, mineral mixture 12%. Lot 6—Corn 85%, mineral mixture 15%.

The mineral mixture used was composed of one-third pulverized limestone, one-third steamed bone meal, and one-third iodized salt. Pasture area varied from one to two acres, increasing as the amount of minerals added to the ground corn increased.

Carcass Studies

All hogs to be slaughtered were trucked to Kingan and Company, Indianapolis, Indiana, for processing. Hogs reaching the required weight were weighed off experiment in the morning of the day to be slaughtered. Individual pre-kill weights were obtained upon arrival at Indianapolis. The experimental hogs were killed at the first of the afternoon kill and were followed through the plant until the carcasses were in the cooler. Carcass identification was maintained by tattooing each hog with an individual number before it was slaughtered.

Carcasses were handled in the same manner in each of the four trials. After chilling 24 hours, carcass measurements were made on the rail and cutting followed immediately by a standardized procedure (Chicago Board of Trade Specifications). A special crew as assigned under the direction of the same man during the entire series for the cutting of all carcasses. Weights of all cuts were recorded individually to the nearest ounce.

The variation in the number of carcasses during the trials was due to several factors: (1) distance to processing plant which did not permit individual slaughterings; (2) extreme treatment response variations within lots; and (3) processing mishaps in the plant.

Three methods were used to measure the ratio of lean to fat in the carcasses. These were: (1) average backfat depth; (2) yield of the four lean cuts (hams, loins, picnics, and Boston butts); and (3) chemical composition of the meat. Following the recording of the weight data, the entire right half of each carcass was skinned and boned. The meat was taken to Kingan's Research Laboratory where it was ground and thoroughly mixed. Thus, a representative sample of meat from each carcass was obtained for chemical analysis.

Chemical composition of meat was assumed to be a true measure of the ratio of lean to fat in the carcasses. Between treatment correlations, from individual carcass data, were used as an evaluation of average backfat depth and yield of the four lean cuts as methods for determining the actual leanness of carcasses.

Results

Feeding Trials

Experiment 1. Table 2 presents a summary of the growth and feed data. In 45 days the pigs in Lot 2, while on a full feed of corn and supplement, reached 125 lb. average weight. Daily gain averaged 1.71 lb. and only 265 lb. of corn and 38.5 lb. of supplement were required

per 100 lb. of gain. The oats fed, following the corn period, were crimped to reduce dustiness, possible wastage and to aid digestion. Pig acceptance of the crimped oats was good and wastage was slight.

TABLE 2. SUBSTITUTING OATS FOR CORN DURING PART OR ALL OF THE FEEDING PERIOD AND OMITTING GRAIN FROM THE RATION AT 50 OR 125 LB.

(Experiment 1—Landino clover-alfalfa pasture)

Lot number	1	2	3	4	5
Treatment	Corn	Corn to 125 lb; then oats	Oats	Corn to 125 lb; no grain	No grain
Number of pigs	12	12	12	12	11[a]
Av. initial wt., lb.	47.8	47.9	47.9	47.7	46.8
Av. final wt., lb.	228	231	228	232	225
Av. daily gain, lb.	1.94	1.73	1.57	.59[e]	.68[f]
Av. number days on feed	93	106	115	314	261
Av. daily feed, lb.					
Corn	5.75	4.54[b]	...	4.28[c] 7.26[d]	8.91[d]
Oats	...	6.71[b]	5.75	...	...
Supplement	.68	1.13	.94	.74	.83
Minerals	.01	.01	.01	.04	.03
Salt	.005	.02	.02	.004	.01
Silage	...	...	...	11.2[b]	11.6[b]
Av. feed per 100 lb. gain, lb.					
Corn	296	265[b]	...	254[e] 283[d]	285[d]
Oats	...	384[b]	367	...	...
Supplement	35.2	65.2	59.9	126	122
Minerals	.7	.7	.8	6.9	4.1
Salt	.3	1.0	1.0	.7	.6
Silage	...	...	...	6211[b]	6906[b]

[a] One pig was removed from the experiment during the pasture period.
[b] For period fed only.
[c] Initial corn period.
[d] Final corn period (finishing).
[e] Initial corn period, 1.68; pasture period, 0.46; silage period, 0.18; and final corn period, 2.56 lb.
[f] Pasture period, 0.62; silage period, 0.14; and final corn period, 3.13 lb.

The daily gain, during the 61-day oats period, averaged 1.75 lb. Maximum oats consumption was not reached until the third week. The average daily intake of oats was 6.71 lb. and protein supplement was 1.48 lb. The supplement eaten was 124% over the average for the corn period (a 135% increase above the control pigs in Lot 1 for the same

period). Each 100 lb. of gain required 384 lb. of oats and 84.6 lb. of supplement.

Minerals eaten by the pigs did not vary between the two periods (corn and oats); however, salt consumption was about four times more during the oats as compared with the corn period.

Wastage was not a serious problem when oats were fed throughout the feeding period, although the pigs did sort the hulls out to some degree. Observation of the debris around the feeder revealed an insignificant percentage of oat kernels.

Average daily supplement consumption was 38.2% more in the lot fed oats (Lot 3) than it was in the control lot (Lot 1). Also, the average daily salt intake was approximately four times greater in the oats lot than in the control lot. Average daily gains were significantly reduced with a corresponding decrease in feed efficiency and an increase in length of feeding period.

The treatment in Lot 4 was designed to promote maximum early development of muscular and skeletal tissues in pigs that would have a capacity to consume large quantities of forage when the grain portion of the ration was omitted. It required 47 days for this lot of pigs to reach an average weight of 125 lb. while given free access to shelled corn and protein supplement. During this initial corn period, the pigs gained 100 lb. for each 254 lb. of corn and 31.8 lb. of supplement. Average daily gain was 1.68 lb.

The ration was changed abruptly after the 125 lb. weight was attained. This resulted in a period of weight loss which continued for about three weeks. A gradual change of rations probably would have minimized this "shock."

No actual measure was kept of the forage consumed during the pasture period. A one-acre plot was closely grazed; later in the season, the lot had additional pasture area. Average daily gain decreased to 0.46 lb. The 12 pigs averaged 170 lb. at the close of the grazing period. Supplement required to produce 100 lb. of gain increased to 163 lb.

Severe cold weather forced a change in the planned treatment. The pigs were transferred to a feeding barn (after 140 days on treatment) where grass silage replaced pasture. The silage was a mixture of grasses and legumes which was preserved with 150 lb. of corn-and-cob meal plus 100 lb. of ground corn cobs per ton of freshly chopped forage.

Maximum silage consumption was attempted by feeding silage three times per day. Wastage was high—between 45 and 50% throughout the period. This was true regardless of the amount of silage offered, up

to 250 lb. per day for the 12 pigs. Beyond this amount wastage increased rapidly. The pigs would not eat the coarse material in the silage; thus, to obtain maximum consumption, wastage was not considered. The silage was fed in troughs which were cleaned before each feeding. Protein supplement was fed at the initial limited rate (0.75 lb. per pig daily). The supplement was modified to include vitamin D, riboflavin, calcium pantothenate, niacin and thiamine at a level sufficient to meet the daily requirements for these vitamins. The mineral mixture was changed to two parts bone meal and one part trace mineralized salt.

The silage period was 168 days. Silage actually consumed averaged 11.2 lb. per head daily, 6211 lb. of silage and 413 lb. of supplement being required per 100 lb. of gain. Gains were variable throughout the period averaging 0.18 lb. daily, decreasing towards the latter portion of the period. This led to a decision to "finish" this lot of pigs on a self-fed corn-supplement ration. One pig was slaughtered during the period after 81 days on silage or 221 days on treatment.

The "finishing" period averaged 14 days for the 11 pigs remaining, the average daily gains increased to 2.56 lb. Corn intake was 7.26 lb. per head daily; supplement 1.27 lb. and only 283 lb. of corn and 49.5 lb. of supplement were needed to produce 100 lb. of gain.

Lot 5 pigs, which were given no grain throughout the experiment, also required a period of silage feeding. One pig in the lot had severe flu and was removed at 119 days. The others were transferred to a feeding barn and fed in the same manner as Lot 4. The 11 pigs gained 0.62 lb. per head daily during the 140 days on pasture. Average weight was 141 lb. requiring 111 lb. of supplement to produce 100 lb. of gain during the pasture period.

Grass silage was fed for 84 days. Gains decreased as the period progressed. Daily gain averaged only 0.14 lb. and the average weight was only 153 lb. at the end of the period. Consumption of silage did not vary significantly during the period nor from Lot 4. Daily intake was 11.6 lb. per pig; excluding silage refused. More total feed was required to produce 100 lb. of gain (6906 lb. of silage and 438 lb. of supplement) than in Lot 4.

After this silage period, the lot was divided into two groups. Group 5A (6 pigs) was given a ration of shelled corn, protein supplement, and mineral mixture self-fed, free choice. Group 5B (5 pigs) continued on grass silage for two more weigh periods (28 days), but gains continued to decrease and this group was also changed to the corn-supplement ration. For the "finishing" period, Group 5A pigs required an average

of 18 days; those in Group 5B, 24 days. Average daily gains were 3.57 and 2.86 lb., respectively. Combined, the pigs averaged 3.13 lb. daily gain while on the corn-supplement ration. The average daily feed intake was 8.91 and 1.77 lb. of shelled corn and supplement respectively; 285 lb. of corn and 56.5 lb. of supplement were required to produce 100 lb.

TABLE 3. THE EFFECT OF LIMITING THE CORN INTAKE ON PASTURE

(Experiment 2—Ladino clover-alfalfa pasture)

Lot number	1	2	3	4
	Percentage of full feed of corn			
Treatment	100	90	72	53
Number of pigs	10	10	10	10
Av. initial wt., lb.	54.1	53.9	54.2	54.4
Av. final wt., lb.	227	221	223	228
Av. daily gain, lb.	1.63	1.41	1.23	1.02
Av. number days on feed	106	118	138	171
Av. daily feed, lb.				
Corn	5.18	4.67	3.74	2.73
Minerals	.01	.01	.01	.01
Salt	.01	.01	.01	.01
Total	5.20	4.69	3.76	2.75
Av. feed per 100 lb. gain, lb.				
Corn	318	332	304	269
Minerals	.7	.5	1	1
Salt	.7	.5	1	1
Total	319.4	333	306	271

of gain. These figures are slightly higher than those observed in the comparable (slightly shorter) period for Lot 4.

Experiment 2. A summary of gains and feed data is given in table 3. Average daily gains decreased as the corn allowance decreased. The feeding period lengthened (up to 65 days) as the corn allowance decreased. Pigs fed a restricted level of corn (53 or 72% of full feed) utilized their feed more efficiently than did those on a full feed or near a full feed of corn. This was true even though the feeding period was prolonged in the more restricted lots. Lot 2 (90% of full feed) deviated slightly from a general trend in the experiment, requiring more feed per 100 lb. of gain than in the full-fed lot.

Experiment 3. Data concerning the gains and feed requirements for this trial are presented in table 4. The results of this trial parallel those

observed in Experiment 2. There was a significant lowering of the average daily gains as the corn allowance decreased and an increase in feed efficiency. There was also a corresponding increase in length of feeding period with reduced gains.

Experiment 4. Gains and feed data are summarized in table 5. All levels of minerals fed, except 3% (Lot 2), decreased daily gains compared with the pigs fed minerals free choice (Lot 1). These decreases were statistically significant above the 6% minerals level.

TABLE 4. THE EFFECT OF LIMITING THE CORN INTAKE ON PASTURE

(Experiment 3—Ladino clover-alfalfa pasture)

Lot number	1	2	3	4	5	6
	Percentage of full feed of corn					
Treatment	100	80	70	60	50	40
Number of pigs	12	12	12	12	12	12
Av. initial wt., lb.	49.9	50.1	49.4	50.4	49.9	49.7
Av. final wt., lb.	225	220	222	226	222	223
Av. daily gain, lb.	1.75	1.46	1.31	1.19	1.10	.95
Av. number days on feed	100	118	132	148	158	183
Av. daily feed, lb.						
Corn	5.79	4.48	4.01	3.56	3.00	2.43
Minerals	.06	.06	.05	.04	.04	.04
Total	5.85	4.54	4.06	3.60	3.04	2.47
Av. feed per 100 lb. gain, lb.						
Corn	331	306	307	299	273	256
Minerals	3	4	3	3	4	4
Total	334	310	310	302	277	260

Daily feed intake increased above the control lot in all treatments, even with the high percentage of minerals included. However, corn intake declined gradually as the minerals increased above the 3% level.

Pigs fed minerals free choice, or near a normal level of minerals (3%), utilized the corn more efficiently than did those with higher levels of minerals.

A summary of the minerals data (actual percent of minerals consumed, grams of mineral elements, and the calcium:phosphorous ratios of the feed mixture consumed daily) is given in table 5. The most rapid gains were made on the ration containing a calcium:phosphorus ratio of 1.67:1 (Lot 2—3% minerals). The poorest gains were made in Lot 6 (15% minerals) with a ratio of 3.49:1.

Carcass Studies

Experiment 1. Carcass data are summarized in table 6. Dressing percentage decreased as the total energy level of the treatments decreased. The actual shrinkage from pre-kill weight to the chilled carcass weight for Lots 1, 2, 3, 4 and 5 averaged 64.4, 67.7, 70.9, 81.2 and 80.1 lb. respectively. This indicates that as the amount of fibrous feed (oats or

TABLE 5. THE EFFECT OF FEEDING VARIOUS LEVELS OF A MINERAL MIXTURE COMBINED WITH GROUND CORN

(Experiment 4—Ladino clover-alfalfa pasture)

Lot number	1	2	3	4	5	6
Treatment	Ground corn and minerals free choice	Percentage of mineral mixture				
		3	6	9	12	15
Number of pigs	12	12	12	12	12	11[a]
Av. initial wt., lb.	48.1	47.9	48.0	48.2	47.8	48.2
Av. final wt., lb.	225	227	225	223	225	227
Av. daily gain, lb.	1.51	1.60	1.45	1.43	1.28	1.22
Av. number days on feed	117	112	122	122	139	147
Av. daily feed, lb.						
Ground corn	4.76	5.29	5.22	5.07	4.89	4.85
Minerals	.02	.16	.33	.50	.67	.85
Total	4.78	5.45	5.55	5.57	5.56	5.70
Av. feed per 100 lb. gain, lb.						
Ground corn	315	330	360	354	384	399
Minerals	1	10	23	35	52	70
Total	316	340	383	389	436	469
Mineral mixture consumed daily, %	.42	2.94	5.95	8.98	12.1	14.9
Mineral elements counsumed daily (minerals+corn)						
Calcium, gm.	2.54	16.9	34.4	52.0	69.4	87.9
Phosphorus, gm.	6.31	10.1	13.9	17.6	21.2	25.2
Salt, gm.	3.04	24.2	49.9	75.7	101.4	128.6
Calcium: phosphorus ratio	0.40	1.67	2.47	2.95	3.27	3.49

[a] One pig was removed due to prolonged subnormal gains following 126 days on treatment.

pasture) increased, so did the shrinkage. The greatly increased shrinkage of the two lots fed silage (4 and 5) was due to the increased proportion of internal organs to the total body weight.

There was a highly significant ($P<0.01$) increase in the percentage of lean in the carcasses of Lots 4 and 5 (compared with Lot 1) as

measured by average backfat thickness, yield of the four lean cuts, or chemical analysis of the meat sample. There was a slight decrease in average backfat depth in the oats lot (Lot 3), however, it was not significant. Feeding oats during the last 100 lb. of gain (Lot 2) did not reduce the backfat depth. Yield of the four lean cuts showed a slight

TABLE 6. THE EFFECT ON CARCASS DEVELOPMENT OF SUBSTITUTING OATS FOR CORN DURING PART OF ALL OF THE FEEDING PERIOD AND OMITTING GRAIN FROM THE RATION AT 50 OR 125 LB.

(Experiment 1—Landino clover-alfalfa pasture)

Lot number	1	2	3	4	5
Treatment	Corn	Corn to 125 lb; then oats	Oats	Corn to 125 lb; no grain	No grain
Number of carcasses	10	10	9	10	10
Av. pre-kill wt., lb.	216	220	221	221	219
Av. chilled carcass wt., lb.	152	152	150	150	139
Dressing percentage	70.2	69.2	67.9	67.8	63.4
Av. backfat thickness, in.	2.01	2.01	1.93	1.42	1.30
Av. carcass length, in.	28.4	29.2	29.5	30.4	29.6
Av. yield of: [a]					
Four lean cuts	45.0	46.3	47.2	53.1	53.8
Five primal cuts	60.8	62.1	63.5	66.2	67.4
Av. chemical content of meat: [b]					
Water, %	32.5	33.9	34.6	47.2	49.7
Protein, %	9.4	9.6	9.9	12.2	12.8
Fat, %	57.4	55.9	54.2	39.7	36.8

[a] Percentage of chilled carcass weight.

[b] These figures do not total 100% because ash and other constituents of meat were not determined, and because of experimental error.

increase as a result of oats feeding, either throughout the feeding period or during the last 100 lb. of gain. There was a significant ($P<0.05$) increase in the yield of the four lean cuts in Lots 4 and 5 over the oats fed pigs in Lots 2 and 3.

Chemical analysis of the meat from each carcass verified the results noted above. There was a highly significant increase in the percent of protein and water and a decrease in the percent of fat in carcasses of pigs from Lots 4 and 5 compared with the other lots. There was a slight decrease in fat percentage and an increase in protein percentage with the use of oats. These were not significant.

Experiment 2. Table 7 contains a summary of the carcass data for this trial. Average backfat thickness was very significantly reduced

($P<0.01$) in lots receiving 72 and 53% of full feed in comparison with the full-fed lot. There was also a highly significant reduction in backfat depth in the 53% full-fed lot in comparison with the 90% full-fed lot. The yields of the four lean cuts parallel the backfat measurements. There were highly significant ($P<0.01$) increases in the lean cut yield when the corn intake was reduced to 72 and 53% of a full feed.

TABLE 7. THE EFFECT ON CARCASS DEVELOPMENT OF LIMITING CORN INTAKE ON PASTURE

(Experiment 2—Ladino clover-alfalfa pasture)

Lot number	1	2	3	4
	Percentage of full feed of corn			
Treatment	100	90	72	53
Number of carcasses	8	8	8	9
Av. pre-kill wt., lb.	216	214	221	219
Av. chilled carcass wt., lb.	152	146	154	149
Dressing percentage	70.6	68.1	69.7	67.7
Av. backfat thickness, in.	1.99	1.89	1.73	1.56
Av. carcass length, in.	28.8	28.2	29.0	28.9
Av. yield of: [a]				
Four lean cuts	45.4	43.8	46.7	49.0
Five primal cuts	62.8	60.5	63.3	65.4
Av. chemical content of meat: [b]				
Water, %	34.4	34.3	37.3	39.7
Protein, %	9.0	9.1	10.0	10.5
Fat, %	56.3	56.2	51.9	48.8

[a] Percentage of chilled carcass weight.
[b] These figures do not total 100% because ash and other constituents of meat were not determined, and because of experimental error.

Chemical analysis for fat and protein verifies the first two methods of determining the ratio of lean to fat. The protein content of the meat increased and the fat content decreased as the corn intake was reduced.

Experiment 3. A summary of the carcass data is presented in table 8. Each of the three methods of measuring the ratio of lean to fat showed significant increases as the percentage of a full feed of corn was decreased. Backfat thickness decreased steadily (highly significant) as the percentage of a full feed of corn was reduced from the amount consumed by the self-fed lot. Also, the averages of backfat thickness among the six lots of pigs increased significantly ($P<0.05$) for a 20% increase in the amount of corn fed (example: from 40 to 60%). The four lean cut yields agree with the average backfat findings, yield increasing as

corn fed was reduced. The differences in the four lean-cut yield between the full-fed pigs and those hand-fed limited amounts of corn in the other five lots were highly significant. Fully supporting the results shown by the average for backfat thickness and the four lean cut yield was the fat content of the meat. The fat (ether extract) in the meat dropped from a 57.3% average for the full-fed pigs to 44.1% for those hand-fed

TABLE 8. THE EFFECT ON CARCASS DEVELOPMENT OF LIMITING THE CORN INTAKE ON PASTURE

(Experiment 3—Ladino clover-alfalfa pasture)

Lot number	1	2	3	4	5	6
	Percentage of full feed of corn					
Treatment	100	80	70	60	50	40
Number of carcasses	9	9	9	10	9	10
Av. pre-kill wt., lb.	220	216	220	222	217	223
Av. chilled carcass wt., lb.	156	151	153	153	148	148
Dressing percentage	71.1	69.8	69.2	68.9	68.2	66.5
Av. backfat thickness, in.	2.09	1.89	1.77	1.73	1.61	1.46
Av. carcass length, in.	28.9	29.4	29.6	30.2	29.9	30.1
Av. yield of: [a]						
Four lean cuts	46.5	49.3	49.8	50.7	50.8	52.6
Five primal cuts	64.8	66.3	66.3	66.7	66.4	68.6
Av. chemical content of meat: [b]						
Water, %	34.0	37.4	39.3	39.4	40.6	43.6
Protein, %	8.8	10.2	10.2	10.1	10.6	11.3
Fat, %	57.3	52.5	49.8	49.6	47.7	44.1

[a] Percentage of chilled carcass weight.
[b] These figures do not total 100% because ash and other constituents of meat were not determined, and because of experimental error.

40% of a full feed. Chemical fat averages were significantly ($P<0.05$) lower in the lots hand-fed reduced allowances of corn.

Experiment 4. The summary of carcass information is given in table 9. Average backfat depth decreased as the minerals in the ration increased above the 6% level. A highly significant decrease in backfat thickness was observed in the 15% minerals lot (Lot 6) in comparison with the minerals free choice lot (Lot 1), the 3% lot (Lot 2), and the 6% minerals lot (Lot 3). The four lean cut yields increased as the minerals level of the rations increased above 6%. There was a significant increase in the yield of the 15% minerals lot over the control lot. These data are in agreement with the average backfat thickness data.

The 3% minerals lot (Lot 2) deviated from the general trend in

carcass data as was the case in the feed data. There was a highly significant increase in the thickness of backfat and a reduction in the four lean cut yield compared with the control lot (Lot 1).

TABLE 9. THE EFFECT ON CARCASS DEVELOPMENT OF FEEDING VARIOUS LEVELS OF A MINERAL MIXTURE COMBINED WITH GROUND CORN

(Experiment 4—Ladino clover-alfalfa pasture)

Lot number	1	2	3	4	5	6
Treatment	Ground corn and minerals free choice	Percentage of mineral mixture				
		3	6	9	12	15
Number of carcasses	10	10	10	10	10	10
Av. pre-kill wt., lb.	219	219	217	215	220	221
Av. chilled carcass wt., lb.	154	155	154	152	153	152
Dressing percentage	70.3	70.8	71.0	70.6	69.3	68.9
Av. backfat thickness, in.	1.81	2.04	1.88	1.74	1.73	1.59
Av. carcass length, in.	29.2	29.0	29.2	29.2	29.6	29.6
Av. yield of: [a]						
Four lean cuts	48.3	46.9	48.0	48.7	50.2	50.9
Five primal cuts	64.7	63.8	64.6	65.2	66.2	66.6
Av. chemical content of meat: [b]						
Water, %	35.9	33.3	34.8	36.7	37.3	39.4
Protein, %	9.9	9.0	9.8	10.0	10.5	11.2
Fat, %	52.7	56.3	54.3	51.8	50.7	48.2

[a] Percentage of chilled carcass weight.
[b] These figures do not total 100% because ash and other constituents of meat were not determined, and because of experimental error.

Discussion

Effect on Gain, Feed Efficiency and Carcass Quality

Oats. Previous investigations (Axelsson and Eriksson, 1953; Crampton *et al.*, 1954b; Hutchinson, 1953; Merkel *et al.*, 1953; Whatley *et al.*, 1951; Woodman and Evans, 1947) suggest that the inclusion of fiber, above "normal" levels, tends to produce somewhat leaner pork carcasses. Oats were used to increase the fiber content of the grain rations in the first trial with corn as the basal grain. The attempt was made to reduce the energy level of the ration by substituting oats for corn; however, the pigs seemed to make up the major portion of the reduced energy by consuming greater quantities of protein supplement. Protein supplement consumption increased when oats were substituted for corn in the ration, whether throughout the feeding period or during the last

100 lb. of gain. The large amount of supplement eaten indicated it was used as a source of energy as well as a source of protein.

The average daily gains of each group fed crimped oats were significantly reduced in comparison with the comparable period in the lot fed corn. Eastwood (1914), in his early work with oats, observed a reduction in gains as the proportion of oats in the ration was increased. This is also in agreement with the work done by Vestal (1921), where alfalfa and oat hulls were used as the source of fiber, and by Hutchinson (1953), who fed alfalfa chaff and chaffed peanut hay. Crampton *et al.* (1954b) stated that in addition to reduced gains, they observed a significant increase in feed intake. This was not found in this trial. Consumption of corn and crimped oats were almost identical. A significant decrease in feed efficiency resulted when oats were fed, which is similar to observations by Bohstedt and Fargo (1953), Crampton *et al.* (1954b), Eastwood (1914), and Vestal (1921).

In agreement with trials using increased fiber rations was the fact that in the oats lots the dressing percentage was decreased in comparison with pigs fed corn (Coey and Robinson, 1954; Merkel *et al.*, 1953). Coey and Robinson (1954) reported that this was apparent in experiments where the inclusion of fiber was small. In this trial, however, there was no significant increase in the leanness of the carcasses of pigs fed oats. This may have been due, in part, to the unlimited supply of protein supplement to which the pigs had access during the period when oats were fed which resulted in a higher energy level than was planned. The crude protein content of the ration consumed by the lot of pigs fed crimped oats for the last 100 lb. of gain averaged 18.1% during the 61-day period; it averaged 16.7% for the pigs fed crimped oats during the entire feeding period.

Omitting Grain. Investigations by McMeekan (1940a, 1940b, 1940c, 1941) suggested that more muscular development would result if pigs were liberally fed early in life. He also stated that leaner carcasses could be produced by limited feeding, particularly during the fattening period. Because very little work has been been reported on forcing the consumption of large quantities of pasture, it was decided on this as an indication of the role pasture would play in future trials.

Average daily gains of pigs started on the "no grain" treatment at 125 lb. live-weight were inferior to those made by the lot of pigs started at 47 lb. The abrupt change in treatment at 125 lb. undoubtedly influenced the gains observed in the lot. However, the average daily gains during the following silage feeding period were slightly in favor of the

lot started on the "no grain" treatment at 125 lb. It should be noted also that the silage period was twice as long for this lot as for the lot started on the "no grain" treatment at 47 lb. Gains and feed efficiency data reflect the inability of pigs up to 200–225 lb. to utilize efficiently large quantities of forage as their only source of energy, particularly grass silage. This was true whether the treatment was begun at approximately 50 or 125 lb. liveweight.

Carcass results from pigs fed no grain from either 50 or 125 lb. showed that the treatments produced inferior pork due to the lack of finish. There was a greater tendency for underfinished carcasses in the lot started on the "no grain" treatment at 47 lb. The low dressing percentages obtained from pigs on these treatments were in agreement with observations by Coey and Robinson (1954), Merkel *et al.* (1953), and Whatley *et al.* (1951) resulting from feeding high fibrous rations.

Restricted Corn Intake by Hand Feeding. Data summarizing the feeding periods of two trials of restricted feeding indicate that feed efficiency was improved as the corn intake was decreased to 40% of full feed. Average daily gains decreased and the feeding period increased as the levels of corn fed decreased. These findings are similar to those obtained by other investigators (Edwards, 1930; Ellis and Zeller, 1931; Robison, 1935; Smith *et al.*, 1950; Weaver, 1927; Winters *et al.*, 1949). Pasture utilization was increased in these trials which resulted in more gain per unit of grain consumed. The first trial in this series of experiments indicated that pasture could be utilized above the level normally consumed on a full feed of grain.

Carcass data indicate that leaner carcasses were produced with the reduction of corn intake by hand feeding limited amounts. Backfat thickness decreased steadily as the corn intake was reduced from lot to lot and the yield of the four lean cuts increased with each reduction of feed. Chemical analysis of the meat added support to the first two methods in that the fat percentage decreased and the protein and water content increased as the percent of a full feed was reduced. Smith *et al.* (1950) and Winters *et al.* (1949) reported a reduction of backfat and leaner carcasses from hogs fed a restricted diet. Other investigators also have reported that the proportion of lean to fat in the carcasses of pigs can be changed to a certain extent by the level of feeding (Crampton and Ashton, 1945; Crampton *et al.*, 1954a; Ellis and Zeller, 1931, 1934; Robison *et al.*, 1952).

There was no indication of reduced quality of carcass or meat except when 40% of a full feed was fed, when lowered carcass quality was due

to lack of finish. These trials indicate that 50 to 70% of a full feed of corn was a desirable level of feeding pigs pastured on good Ladino clover-alfalfa pasture plus a mineral mixture but without protein supplementation to increase the ratio of lean to fat in the carcasses. However, an increase in the length of feeding period was necessary.

Limiting the Corn Intake with Minerals. The previous trials in this research indicated that efficient, economical gains could be produced by limiting corn intake, making maximum utilization of good pasture. Riggs *et al.* (1953) reported that salt could be used to limit the consumption of concentrates self-fed to beef cows. It has also been observed that high levels of calcium or an imbalance of the calcium:phosphorus ratio tends to reduce feed consumption (Bohstedt *et al.*, 1942; Shewsbury and Vestal, 1943).

Experiment 4 was an attempt to reduce corn intake by adding various levels of a mineral mixture on a self-fed program. Consumption on the higher levels of minerals was above that expected. Total feed consumed, as well as the ground corn alone, was above the control lot (corn and minerals fed separately, free choice) in each case. The levels of minerals fed in this trial were not sufficient to interfere markedly with feed consumption.

The 3% minerals lot consumed more corn per day and average daily gains were also the highest. This may have been the result of the interaction of two factors:

1. The inclusion of a near-normal level of minerals may have made the ground corn more palatable resulting in a higher consumption than in the control lot. Aubel *et al.* (1941) stated that pigs could be fed a calcium level of 1% without abnormal results, indicating the calcium level in the 3% mineral-corn mixture was not high enough to be unpalatable. The slightly decreasing amounts of ground corn consumed in the other lots, as the minerals level was increased, may have been due to the increasing amount of calcium or salt or both.

2. The consumption of the 1% salt in the 3% minerals-corn mixture may have stimulated the consumption of water and in turn more feed.

In all instances, however, the feed required to produce 100 lb. of gain increased above the control lot with each increase in the minerals content of the ration. Bohstedt *et al.* (1942) reported with pigs on pasture or in dry lot a calcium:phosphorus ratio of approximately 1.25 in the grain mixture was found to be most efficient. Shrewsbury and Vestal (1943) reported a calcium:phosphorus ratio of 1.5 gave the greatest growth and as the ratio was increased a significant and progressive reduction in

growth resulted. They also noted that the feed required to produce 100 lb. of gain increased as the ratio increased toward the optimum for growth. It was concluded that ratios of calcium to phosphorus between 1.4 and 2.4 produced the most satisfactory growth. Using the calcium: phosphorus ratios of the feed consumed in this trial, the growth rates obtained are similar to those observed by Shrewsbury and Vestal (1943).

Investigations by Colovos *et al.* (1953, 1954), feeding high levels of calcium to dairy heifers, indicate lowering of digestibility of both protein and energy in grass silage. This was apparent when 100 gm. of limestone was fed each cow per day; 50 gm. had no significant effect. Therefore it seems reasonable to believe that the consumption of the large quantities of calcium by pigs in this trial (up to 88 gm. per pig daily) resulted in lower digestibility of nutrients consumed.

TABLE 10. CARCASS CORRELATIONS *

Experiment	Four lean cuts as % of chilled carcass wt. and % fat by chemical analysis	Average backfat depth and % fat by chemical analysis	Four lean cuts as % of chilled carcass wt. and average backfat depth
1	—.96	.93	—.90
2	—.83	.73	—.78
3	—.91	.84	—.75
4	—.92	.74	—.79

* Each significant at the 1% level.

Carcass data were similar to those observed in the two trials where corn was hand-fed at various percentages of a full feed. The leanness of carcasses increased as the minerals fed to the pigs increased above the 6% level. It appears that the increased minerals content of the feed did not result in a significant reduction in feed intake. However, it may have reduced the digestibility of the feed consumed and in turn would have reduced the nutrients available to the pigs. Hence leaner carcasses resulted.

Carcass Correlation Data. At the outset of these trials, it was planned to determine an easy yet accurate method of estimating the leanness of hog carcasses. It was thought that chemical analysis would be the most accurate estimate. It became the base with which other estimates were compared. Correlation data are presented for the entire series of trials in table 10.

It was found that both carcass methods of estimating the leanness (or fatness) of carcasses gave highly significant correlations with the

chemically determined fat (ether extract). These two methods were the four lean cut yield as a percentage of the chilled carcass weight and the average of three backfat measurements. The higher and more consistent correlations resulted from the four lean cut yield.

Also, there was a significant correlation between rate of gain and the degree of fatness in the carcasses as determined by all three methods. The most rapid gains produced the fattest carcasses. Correlation coefficients between average daily gain and average backfat depth for individual hogs were 0.89 (Experiment 3) and 0.57 (Experiment 4); and between average daily gain and the four lean cut yield of the chilled carcass for individual hogs were 0.68 (Experiment 3) and 0.47 (Experiment 4); and between average daily gain and the percent fat by chemical analysis for individual hogs were 0.88 (Experiment 3) and 0.46 (Experiment 4). These correlations were all significant at the 1% level.

Summary

Leaner market hog carcasses were produced when the energy level of the rations was appreciably reduced. This was accomplished by eliminating grain from the ration at 50 and 125 lb.; limiting the corn intake by hand feeding various percentages of a full feed; and mixing high levels of minerals with ground corn.

The elimination of grain from the ration resulted in an extremely long feeding period and inferior carcasses due to a lack of finish. Oats fed throughout the feeding period or during the last 100 lb. of gain did not significantly reduce the fat content of the carcasses when protein supplement was fed free choice.

Indications were that a level of 50 to 70% of a full feed of corn was desirable to increase the proportion of lean to fat in carcasses without seriously reducing rate of gain and lengthening the feeding period.

Apparently the actual energy available to the pig was lowered by the inclusion of high levels of a mineral mixture with ground shelled corn. The high intake of calcium or the imbalance of the calcium:phosphorus ratio may have reduced the digestibility of corn in the ration thus resulting in the lowering of available energy. A significant increase in the lean content of carcasses was not reached until 12% minerals was included in the ration.

As the available energy was reduced by all three methods, average daily gain was decreased and the feeding period increased. Feed effi-

ciency was decreased in all cases except by limited feeding of corn on pasture where it was increased.

A study of correlation data obtained from 198 carcasses in this series of trials was made. It was indicated that the yield of the four lean cuts as a percentage of the chilled carcass weight was a more accurate estimate of the leanness of carcasses than the average backfat thickness. The true fat percentage of the carcasses was determined by chemical analysis of a sample of the meat of the entire right half of each carcass studied.

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BEEF CARCASS COMPOSITION AND YIELD OF WHOLESALE CUTS AS ESTIMATED FROM LEFT AND RIGHT SIDES

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EXPERIMENTAL beef cutting reduces the commercial value of carcasses. Detailed cutting studies must usually be conducted in meats laboratories of colleges and experiment stations. Labor and facilities are usually limited at these laboratories. Accurate experimental data are necessary, and it is desirable to determine the relative accuracy of data obtained by processing one side of a beef carcass compared to the entire carcass. If a single side would yield data of acceptable accuracy, a real saving in labor and commercial value of the remaining side would result.

Procedure

Seventy-seven cattle produced at Substation 23 of the Texas Agricultural Experiment Station were slaughtered in the meats laboratories located on the campus of the A. and M. College of Texas and the Prairie View A. and M. College of Texas in May 1954. The cattle were used in performance testing studies as described by Warwick *et al.* (1955). Such studies require measurement of the feedlot performance of bull calves before selection of outstanding individuals for herd sires. Thirty-three rejected bull calves from the group which completed the feeding trial in 1954 were slaughtered and processed at Prairie View. Forty-four steers selected at random within sire groups were slaughtered and processed at College Station. The cattle were about 14 months of age, and had been fed in drylot about 165 days.

Both sides of the carcasses were cut by standard procedure described by Hankins and Howe (1946). Before cutting, some measurements were made on each side in the manner described by Naumann (1951). Estimation of the physical composition of the carcasses was made by processing the 9–10–11 rib cut sample from the left side in the manner of Hankins and Howe (1946). The 9–10–11 rib cuts from 15 right sides were processed for comparison.

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[2] Cattle were produced on a project integrated into the S–10, Southern Regional Beef Cattle Research, in cooperation with the U.S.D.A.

Results and Discussion

Carcass yields from the steers in this study were reported by Butler *et al.* (1956). This statistical study was made to measure the accuracy of information obtained by cutting only one side of a carcass.

It was assumed that accurate splitting would divide the carcass into two symmetrical sides and that either side would give representative data for the carcass. One well recognized departure from bilateral symmetry in beef carcasses is the difference in attachment of the kidney knob (perirenal fat) caused by the pressure of the paunch on the left side.

The mean difference was tested by use of the "t" test. In addition, correlation coefficients were determined between weights and measurements from the left side as compared to the mean of both sides. Obviously a part-whole correlation resulted from this comparison, but this seemed to answer the question of whether an accurate estimate of carcass values could be obtained from one side.

No bias was found between sides in measurement of length of leg or body, or thickness of shoulder or round.

The depth of chest was measured at the seventh thoracic vertebra from the ventral edge of the spinal canal to the ventral side of the sternum, with the steel tape parallel to the floor. The significant difference indicates, perhaps, a tendency to saw the sternum off center. This explanation may also apply to the significant difference in mean brisket weight.

The difference in area of eye muscle cannot be explained. Possibly there is a consistent difference in the technique of separating fore and hindquarter. The loin eye muscle area was measured at a uniform spot in the lumbar area, however, and the difference is almost the same. Possibly the longissimus dorsi is developed more on the left side, but it is more likely that there was a consistent variation in technique.

Differences in thickness of fat in the two areas shown are of about the same magnitude, but the explanation is not apparent. Fat thicknesses averaged about 11 mm., and the standard deviation of the mean differences between sides was more than 2 mm., which indicated a rather high percentage variation.

The difference in hindquarter weights is easily explained by the practice of leaving the hanging tender (diaphragm muscle) attached to the left side. The 1 lb. difference in mean hindquarter weight was due almost entirely to the heavier weight of the left kidney and fat, which was weighed with the hanging tender attached.

The round has thick muscling, and skeletal check points cannot be used as guides for cutting to the extent possible in forequarter cuts. A slight bias in technique on different sides in removal of the rump from the round probably caused the variation in weight of the rump,

TABLE 1. ACCURACY OF BEEF CARCASS DATA ESTIMATES OBTAINED FROM LEFT AND RIGHT SIDES

Item	No. of carcasses	Standard error of mean difference	Mean difference[a]	Probability of chance occurrence less than
Length of body	77	0.11	0.13 cm.	N.S.[b]
Length of leg	75	0.10	0.14 cm.	N.S.
Width of shoulder	75	0.18	−0.07 cm.	N.S.
Width of round	76	0.08	−0.13 cm.	N.S.
Depth of chest	76	0.12	0.41 cm.	.01
Area of eye muscle	44	0.09	0.39 sq. in.	.001
Thickness of fat over eye muscle	42	0.40	−0.59 mm.	N.S.
Area of loin eye muscle	42	0.05	0.29 sq. in.	.001
Thickness of fat over loin eye muscle	42	0.33	−0.87 mm.	.02
Side weight	44	0.35	0.10 lb.	N.S.
Hindquarter weight	77	0.24	1.00 lb.	.001
Kidney and fat weight	77	0.13	0.98 lb.	.001
Forequarter weight	77	0.46	−0.53 lb.	N.S.
Rib weight	77	0.17	−0.18 lb.	N.S.
Short plate weight	77	0.14	−0.14 lb.	N.S.
Foreshank weight	76	0.08	0.08 lb.	N.S.
Brisket weight	77	0.12	−0.68 lb.	.001
Chuck weight	77	0.43	0.62 lb.	N.S.
Flank weight	77	0.16	0.08 lb.	N.S.
Full loin weight	77	0.20	0.03 lb.	N.S.
Short loin weight	77	0.16	0.21 lb.	N.S.
Loin end weight	77	0.19	−0.29 lb.	N.S.
Rump weight	76	0.11	−0.35 lb.	.01
Round, rump off weight	77	0.19	0.67 lb.	.001
Hind shank weight	77	0.08	−0.09 lb.	N.S.
Cushion round weight	77	0.20	0.72 lb.	.001
Hind shank bone	77	0.03	−0.01 lb.	N.S.
Bone weight 9–10–11 rib cut	15	0.03	0.04 lb.	N.S.
Fat weight, 9–10–11 rib cut	15	0.06	0.15 lb.	.05
Lean weight 9–10–11 rib cut	15	0.07	0.10 lb.	N.S.
Total weight, 9–10–11 rib cut	15	0.08	0.27 lb.	.01

[a] Left minus right side.
[b] Not significant, probability greater than .05.

round, rump off, and cushion round (round, rump and shank off). A cutting deviation of a fraction of an inch in this area would result in a fairly large difference in weight of the rump and round.

The mean difference of about ¼ lb. in weight of 9–10–11 rib cuts, though significant statistically, probably would not cause a large error in estimation of carcass composition. Lean and bone weights from these cuts were fairly accurately obtained, and only a small variation was found in weight of the separable fat.

TABLE 2. CORRELATION BETWEEN BEEF CARCASS DATA ESTIMATES OBTAINED FROM THE LEFT SIDE AND THE MEAN OF BOTH SIDES

	No. of carcasses	Mean left side	Mean both sides	Correlation coefficient
Length of body, cm.	77	113.85	113.78	0.993
Length of leg, cm.	75	73.20	73.13	0.992
Width of shoulder, cm.	75	19.56	19.60	0.876
Width of round, cm.	76	20.88	20.95	0.948
Depth of chest, cm.	76	38.80	38.60	0.950
Area of eye muscle, sq. in.	44	8.97	8.78	0.949
Thickness of fat over eye muscle, mm.	42	10.62	10.91	0.960
Area of loin eye muscle, sq. in.	42	8.15	8.01	0.983
Thickness of fat over loin eye muscle, mm.	42	10.12	10.56	0.962
		lb.	lb.	
Side	77	241.71	241.49	0.997
Hindquarter	77	119.28	118.79	0.997
Kidney and fat	77	8.72	8.24	0.980
Forequarter	77	122.43	122.70	0.992
Rib	77	21.47	21.56	0.969
Short plate	77	17.16	17.23	0.976
Foreshank	76	10.40	10.36	0.970
Brisket	77	10.86	11.20	0.956
Chuck	77	63.05	62.74	0.981
Flank	77	13.02	12.98	0.963
Full loin	77	37.05	37.04	0.984
Short loin	77	17.70	17.59	0.969
Loin end	77	19.32	19.47	0.964
Rump	76	10.45	10.63	0.951
Round, rump off	77	50.29	49.96	0.989
Hind shank	77	10.91	10.96	0.991
Cushion round	77	39.43	39.07	0.981
Hind shank bone	77	4.47	4.48	0.982
Bone, 9–10–11 rib cut	15	1.36	1.34	0.910
Fat, 9–10–11 rib cut	15	2.40	2.33	0.990
Lean, 9–10–11 rib cut	15	4.09	4.05	0.974
9–10–11 rib cut	15	7.85	7.71	0.990

Correlation coefficients between estimates obtained from the left side and the mean of both sides are given in table 2.

Very high correlation coefficients were obtained for all values.

The two lowest correlation coefficients were for the width of shoulder and for the bone weight in the 9–10–11 rib cut. The major variation in data for those two factors probably was caused by inaccurate division of the carcass into sides. A slight variation in sawing seems to be unavoidable occasionally even with trained workmen because of the long narrow spinous processes on the thoracic vertebrae.

Summary

Variations in measurements and cut weights from left and right sides of beef carcasses were analyzed. Except for the slightly heavier mean weight of the left hindquarter and left kidney knob caused by leaving the hanging tender attached to the left side, little difference in mean cut weights was found. Slightly heavier briskets on the right side were probably due to a consistent deviation from the center in splitting the sternum. The reason is obscure for the slightly larger area of the left longissimus dorsi muscle as measured at the twelfth rib and also in the lumbar region. A variation in technique is suspected instead of a real difference in muscular development. Small significant differences found in weights of rump, round, and cushion round were thought to be due to cutting technique.

Cutting data obtained from the left side of a carcass apparently is sufficiently accurate for most purposes.

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THE FAT-LEAN RATIO IN THE ROUGH LOIN AS A TOOL IN EVALUATION OF PORK CARCASSES [1]

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THE need for a simplified method of evaluating pork carcasses has long been recognized. Backfat thickness has been used as a measure of carcass fatness for many years, although proof of the existence of such a relationship was lacking until Hankins and Ellis (1934) showed that backfat thickness and percentage of ether extract in the carcass were related. A number of workers (Brown *et al.*, 1951; Whiteman *et al.*, 1953; Pearson *et al.*, 1956) found that specific gravity of the carcass was a more precise measure of leanness than backfat thickness. Other methods that have been suggested for measuring carcass composition include the core method (Aunan and Winters, 1952) and physical separation of selected cuts (McMeekan, 1941).

In spite of the number of methods that have been suggested for measuring carcass leanness, there is still a great need for a more reliable measure. Soule (1950) first used the fat-lean ratio of the rough loin as a measure of leanness. Although this method has been used in conjunction with other studies (Rust, 1953; Vorkapich, 1955) a more comprehensive analysis of the method was needed. Consequently, this study was undertaken to determine whether the fat-lean ratio in the rough loin would be useful in measuring carcass leanness. This investigation was also designed to determine whether certain other carcass measurements were useful in terms of evaluating leanness.

Materials and Methods

Experimental Animals, Carcass Cutting, and Measuring Procedures

A total of 102 hog carcasses were used in this study. Details concerning their origin, breeding, handling, cutting, and measuring procedures have been previously outlined (Pearson *et al.*, 1956).

Area of Lean and Fat-Lean Ratio

The area of lean was determined by planimeter readings of tracings of the rough loin made at the 10th and the last rib. The area of lean as

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traced included both the *Longissimus dorsi* and *Multifidis dorsi* muscles. The latter muscle lies dorsal and adjacent to the *Longissimus dorsi* and contributes to the amount of lean area exposed. In fact, the *Multifidis dorsi* may be included in many tracings of the so-called "eye muscle".

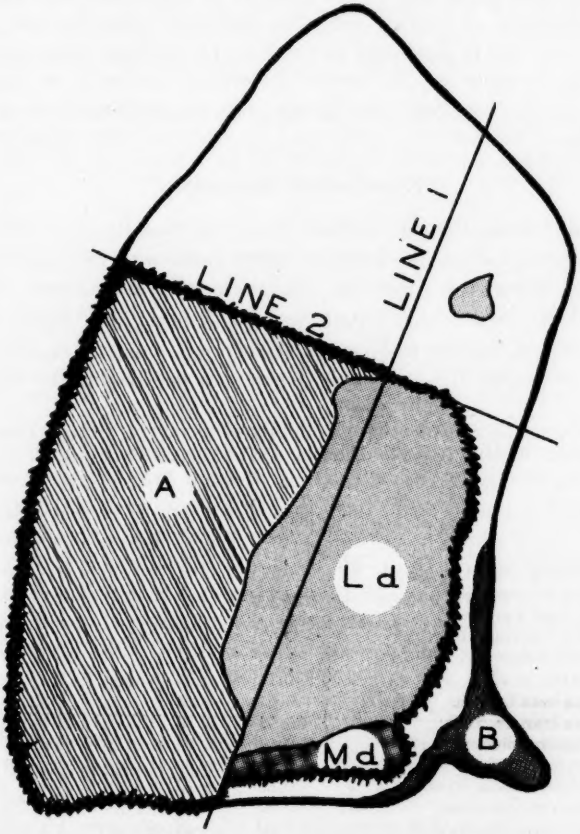

Figure 1. Illustration of procedure in determining fat-lean ratio.

Line 1—drawn through the longest axis of the area of lean.
Line 2—constructed perpendicular to line 1 at the point of intersection with the outer edge of the area of lean.

Ld=*Longissimus dorsi* muscle
Md=*Multifidis dorsi* muscle
Area lean=Ld+Md
Fat-lean ratio=Area fat/Area lean.
A=Area of fat
B=Bone

Since there is considerable variation in the amount of fat area exposed, even under careful cutting procedures, a standard method for proscribing the fat area became necessary. Thus a line was drawn through the longest axis of the area of lean and another line was constructed perpendicular to the first line at the point of intersection with the line circumscribing the area of lean. The method of measuring the areas of fat and lean is illustrated in figure 1. The fat-lean ratio was then obtained by expressing the units of fat area in relation to the units of lean area. In this study, the fat-lean ratio was calculated only at the last rib.

Results and Discussion

Table 1 shows that the fat-lean ratio is significantly correlated with all of the various carcass measures under study with the exception of dressing percentage, where the relationship was nil (—0.02). Other correlations range from —0.62 between fat-lean ratio and percent lean cuts on the live basis to —0.23 between the fat-lean ratio and length of carcass. It is interesting to note that the relationships between

TABLE 1. CORRELATIONS OF FAT–LEAN RATIO WITH OTHER CARCASS MEASUREMENTS, AND MEANS AND STANDARD DEVIATIONS

	Correlation values ratio fat/lean	Mean	Standard deviation
Fat–lean ratio	.....	1.28	0.284
Specific gravity of carcass	—0.59	1.032	0.0066
Specific gravity of ham [a]	—0.54	1.045	0.0071
% lean cuts minus % fat trim [b]	—0.60	21.91 (%)	4.79
Fat back thickness [c]	+0.38	1.77 (in.)	0.20
Length of carcass [d]	—0.23	29.08 (in.)	1.02
Area lean last rib	—0.61	4.51 (sq. in.)	0.57
Area lean 10th rib	—0.53	4.01 (sq. in.)	0.53
Dressing percentage [e]	—0.02	74.99 (%)	1.56
% lean cuts—live basis	—0.62	36.31 (%)	1.70
% lean cuts—carcass basis	—0.60	48.40 (%)	2.39
% primal cuts—live basis	—0.60	48.23 (%)	1.84
% primal cuts—carcass basis	—0.60	64.34 (%)	2.38
% fat trimmings [b]	+0.54	26.49 (%)	2.70
Live probe [f]	+0.33	1.69 (in.)	0.31

[a] Left ham.
[b] Carcass basis.
[c] Average of four measurements taken at 1st rib, 7th rib, last rib, and last lumbar vertebra.
[d] Measured from anterior edge of 1st rib to anterior edge of aitch bone.
[e] Dressing $\% = \frac{\text{Cold Carcass Wt. (Leaf fat out— head off)}}{\text{Live Wt. (off feed 24 hr.)}} \times 100.$
[f] Average 3 probes taken behind shoulders, over loin, and midway between the two points.

the fat-lean ratio and percent lean cuts or percent primal cuts on both the live and carcass basis are practically identical, varying from only −0.60 to −0.62. Likewise, the fat-lean ratio is similarly related to specific gravity of the carcass, with a value of −0.59. Both specific gravity of the ham and percent fat trimmings have a slightly lower degree of association with the fat-lean ratio than other measures of leanness with values of −0.54 and +0.54, respectively.

TABLE 2. RELATIONSHIP OF LENGTH OF CARCASS, DRESSING PERCENTAGE, AREA OF LEAN AT LAST RIB, AND AREA OF LEAN AT 10th RIB WITH CERTAIN MEASURES OF CARCASS LEANNESS

	Correlations			
	Carcass length	Dressing percentage	Area lean last rib	Area lean 10th rib
% lean cuts minus % fat trim[a]	+0.32	−0.22	+0.50	+0.47
% lean cuts—live basis	+0.24	+0.18	+0.56	+0.53
% lean cuts—carcass basis	+0.28	−0.24	+0.53	+0.52
% primal cuts—live basis	+0.32	+0.31	+0.64	+0.58
% primal cuts—carcass basis	+0.38	−0.24	+0.62	+0.59
% fat trim[a]	−0.32	+0.19	−0.41	−0.38

[a] Carcass basis.

The relatively small range in closeness of relationship between the fat-lean ratio and the various measures of carcass cut-out indicate that the fat-lean ratio may be useful in evaluating carcasses where cut-out data are difficult to obtain. However, the question as to whether the ratio offers any advantage over simply measuring the area of lean can well be asked. The correlation between the area of lean at the last rib and the ratio was −0.61, while the corresponding value for the 10th rib was −0.53. The higher relationship for the area of lean at the last rib would be expected since the fat-lean ratio used in calculated all correlations was obtained on the last rib only. Thus, it is not unlikely that the correlation would have been higher had the ratio been determined at the 10th rib.

Table 2 gives a summary of the relationship between carcass cut-out values and the area of lean at both the last and 10th ribs. It is notable that the correlations are all slightly closer for area of lean at the last rib and cut-out than for area of lean at the 10th rib and cut-out. This indicates a slight advantage for use of the area of lean at the last rib, though the difference is probably not of any major importance. Thus, the conclusions of Kline and Hazel (1955) that measurement

of the lean area at either the 10th or last rib is suitable, providing the procedure is standardized in subsequent studies, would seem valid.

Comparison of the correlations obtained for area of lean in relationship to carcass cut-outs (table 2) with those for relationship of cut-outs to the fat-lean ratio (table 1) indicate that there is little advantage in making the additional tracings and calculations involved in obtaining the ratio.

Dressing percentage (table 2) has a rather low relationship to carcass cut-out. Since lean or primal cuts are a part of carcass weight, the existing correlation is primarily an expression of the relationship of the part to the whole. Thus, dressing percentage *per se* is of little importance in evaluating carcass leanness.

The degree of association between carcass length and carcass cut-out is low with the highest correlation being +0.38. Thus, carcass length may be over-emphasized in carcass evaluation programs.

Summary

In this study the fat-lean ratio in cross section of the rough loin at the last rib was investigated as a possible measure of carcass leanness. Correlation coefficients of approximately —0.60 between the fat-lean ratio and several measures of carcass cut-out indicated the relationship may be high enough to be useful when it is impossible to obtain cut-out information. However, the area of lean at the 10th rib or last rib was only slightly less reliable than the ratio of fat to lean for estimating cut-out values.

Consideration of the relationship between either carcass length or dressing percentage and carcass cut-out indicates that major emphasis should be placed on other methods of measuring leanness.

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VARIATION IN THIAMINE CONTENT OF RAW BEEF MUSCLE [1, 2]

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PREVIOUS work has indicated considerable variation in thiamine content of raw meat from different lamb carcasses (Cover *et al.*, 1947; Cover and Smith, 1955) and from different beef carcasses (Cover *et al.*, 1944, 1947). But no clue to the cause of these differences was reported. Wilcox and Galloway (1952) reported that two breeds of lambs differed significantly in the thiamine content of raw meat but no significant difference was obtained in lambs from three other breeds in a different year. Raw meat from their grass-fat lambs was reported to contain significantly more thiamine than that from the fed lambs. The statistical methods used to determine significance were not given.

Some reports in the literature indicate that thiamine is synthesized by microorganisms in the rumen of sheep and cattle (McElroy and Goss, 1939, 1940; Wegner *et al.*, 1940, 1941; Hunt *et al.*, 1941). On the other hand, Hunt *et al.* (1943) reported little evidence that thiamine was synthesized in the rumen with the possible exception of those feeding trials in which the readily available carbohydrate content of the ration was increased. Lardinois *et al.* (1944) also found no evidence to indicate that thiamine was synthesized in the rumen. However, Hunt *et al.* (1941, 1943) and Lardinois *et al.* (1944) suggested that thiamine probably was synthesized, but that it was absorbed or destroyed at a rate greater than its synthesis. If thiamine is synthesized in the rumen, it is likely that an abundance of thiamine is available to the healthy animal. On the other hand, any interruption in its production, or change in its rate of absorption or metabolism might produce variations in thiamine content of the muscles of different animals. Cover and Smith (1955) found that chlortetracycline fed in graded amounts to lambs did not affect the thiamine content of meat. The effect of this antibiotic on thiamine production in the rumen was not determined but it seemed likely that the thiamine producing organisms were resistant to it.

[1] The meat used was from animals raised at Substation 23, McGregor, Texas under a project which is cooperative with the U.S.D.A. and is a part of S-10 Southern Regional Beef Cattle Breeding Project.

[2] The authors wish to acknowledge the assistance of M. J. Garber, Department of Genetics, for his help with the statistical designs and R. L. Smith, Statistical Laboratory, for making the statistical calculations.

[3] Professor and Technician respectively, Department Rural Home Research.

It seemed possible that the rate of absorption or the rate of metabolism of thiamine might be influenced by inheritance. If so, perhaps the thiamine content of the meat also might be affected by inheritance. Testing such an hypothesis became possible when 54 beef animals of known breeding became available.

Experimental Procedure

The meat for the thiamine determinations was obtained from purebred Hereford steers and Brahman × Hereford crossbred steers from

TABLE 1. COMPOSITION OF THE RATIONS

Ration ingredients	Growing ration	Fattening ration	
		Early part	Last part
	1952–3		
Ear corn	0	0	5
Milo grain	20	20	55[a]
Cottonseed meal	15	15	10
Hegari hay	35	35	0
Johnson grass hay	28	28	28
Alfalfa leaf meal	2	2	2
	100	100	100
	1953–4		
Milo grain	20	20	60[a]
Cottonseed meal	15	15	10
Sorghum and Johnson grass hay	32.5	32.5	15
Oats and sweetclover hay	32.5	32.5	15
	100.0	100.0	100

[a] All cattle were fed the growing ration but those on the fattening ration were stepped up in grain by January 5, 1953 or by January 4, 1954.

Hereford cows. These steers from known sires had been grown at Substation No. 23 and were used in tests for heritability of rate of gain (Warwick and Cartwright, 1955). Half of the animals from each sire had been fed a growing ration containing 35% concentrates and the others a fattening ration containing 70% concentrates (table 1). The steers were brought from McGregor to College Station for slaughter in May of each year. They have been used in carcass studies (Butler *et al.*, 1956) and in palatability studies (Cover and Smith, 1956). The 9–10–11 rib cut was separated into fat, lean and bone as one of the tests for fatness (Cover *et al.*, 1956), leaving the entire longissimus dorsi muscle as a by-product. It was frozen and stored until the tests could

be made. In 1953, the longissimus dorsi muscle from the 6–7–8 rib cut was saved also. It was used as one sample and that from the 9–10–11 ribs as the other sample. In 1954, the eyemuscle from the 9–10–11 rib cut was the only piece saved and because the amount of meat was so small, the entire sample was ground before the subsamples were taken. The methods for moisture and ether extract were essentially those described in AOAC. The method for thiamine was essentially that described in Methods of Vitamin Assay of the Association of Vitamin Chemists.

Results and Discussion

Because the reports in the literature were inconclusive regarding the effect of level of carbohydrate in the ration on thiamine production in the rumen, and because half of these animals from each sire received rations containing 35% concentrates and half 70%, it seemed desirable to test the effect of ration on the thiamine content of the meat. There was a possibility that, if more thiamine were synthesized when the readily available carbohydrate content of the ration was increased, the meat from the steers on the fattening ration would have a higher thiamine content than that from steers on the growing ration. The thiamine content averaged by rations within breeds is given in table 2. No data were collected on rumen contents but the difference in thiamine content of the meat from the animals on the two rations was not significant in

TABLE 2. THIAMINE CONTENT OF RAW BEEF AVERAGED BY RATIONS WITHIN BREEDS

Breed	Number of sires	Ration	Number of animals	Average thiamine content, mcg./g.	
				Moist basis	Dry fat-free
		1953 data			
Herefords	4	Growing	4	0.99	4.40
		Fattening	4	0.79	3.50
Brahman × Herefords	4	Growing	4	1.11	4.88
		Fattening	4	1.09	4.85
		1954 data			
Herefords	4	Growing	9	0.84	3.64
		Fattening	9	0.88	3.85
Brahman × Herefords	5	Growing	10	0.96	4.11
		Fattening	10	0.96	4.14

TABLE 3. OUTLINE OF STATISTICAL ANALYSES FOR THIAMINE CONTENT OF RAW BEEF

Source of variation	Degrees of freedom	Mean square	Error term[a]
	1953 data		
Breeds	1	6.69*	S(B)
Rations	1	1.73	R × S(B)
B × R	1	1.54	R × S(B)
Sires within B	6	0.89***	Samples
R × S within B[b]	6	0.40***[b]	Samples
Samples	16	0.05	.....
Total	31	....	.....
	1954 data		
Breeds	1	2.84	S(B)
Rations	1	0.24	R × S(B)
B × R	1	0.15	R × S(B)
Sires within B	7	0.54	Animals
R × S within B	7	0.32	Animals
Animals within S	20	0.66***	Samples
Samples	38	0.009	.....
Total	75	....	.....
	1953 and 1954 data combined		
Years	1	4.77**	Animals
Breeds within Y	2	4.76**	S(B)
Sires within B	13	0.70	Animals
Animals within S	37	0.58***	Samples
Samples	54	0.02	.....
Total	107	....	.....

* Significant at 5% level.
** Significant at 1% level.
*** Significant at 0.1% level.
[a] Error terms were determined by the method of Bennett and Franklin (1954).
[b] Because only one animal from each sire was placed on each ration, R × S(B) represents the animal variation also.

either year (table 3). Thus additional readily available carbohydrate in the feed did not significantly increase the thiamine content of the meat.

Evidence of inheritance of a characteristic may appear as a difference between breeds or as a difference between sires within breeds. The data collected were suitable for testing in both ways. The thiamine content averaged by breeds and by sires within breeds is given in table 4. The difference between breeds was significant in 1953 but not quite significant in 1954 (upper part of table 3). "Sires within breeds" and "rations times sires within breeds", could not be tested with "animals" in 1953 as they were in 1954 because there was only one animal from each sire on each

ration. When the attempt was made to use "samples" (chemical duplicates) as the error term, the variation due to "samples" was so small that the F values which were obtained for "sires within breeds" and for "ration times sires within breeds" seemed unduly large. Then,

TABLE 4. THIAMINE CONTENT OF RAW BEEF AVERAGED BY SIRES AND BREEDS

Breed and sire code	Number of animals	Average thiamine content, mcg./g.	
		Moist basis	Dry fat-free
	1953 data		
H–18	2	0.88	3.89
H–19	2	0.92	4.08
H–30	2	0.89	3.98
H–31	2	0.86	3.84
	Mean of 8 animals	0.89	3.95
BH–23	2	1.00	4.42
BH–26	2	1.03	4.60
BH–27	2	1.30	5.84
BH–28	2	1.06	4.58
	Mean of 8 animals	1.10	4.86
	1954 data		
H–7	4	0.79	3.42
H–27	6	0.89	3.86
H–89	4	0.89	3.90
H–90	4	0.86	3.71
	Mean of 18 animals	0.86	3.74
BH–113	4	0.98	4.25
BH–115	4	0.88	3.76
BH–117	4	1.04	4.49
BH–119	4	0.91	3.95
BH–120	4	0.97	4.19
	Mean of 20 animals	0.96	4.13

"rations" were omitted from consideration (this was possible because the difference between rations was not significant), the data from the two years were treated together (see lower part of table 3) and "sires within breeds" were tested with "animals". With this more adequate error term the difference between sires within breeds was not significant. But the difference between breeds was highly significant (1% level). Thus inheritance, as shown by breed, seems to play a part in how much thiamine will be found in the longissimus dorsi muscle of steers. This

is the first time of which the authors are aware that a significant relationship has been reported between thiamine content of beef and any factor in the history of the beef animal. However this finding gave no insight into the manner by which inheritance influenced the thiamine content.

Because thiamine utilization is related to energy metabolism, it seemed possible that the thiamine content of muscles might be related

TABLE 5. SIMPLE CORRELATIONS BETWEEN THIAMINE CONTENT AND CERTAIN PRODUCTION VARIABLES, CARCASS AND PALATABILITY CHARACTERISTICS

Thiamine content of longissimus dorsi in 9–10–11 rib cut from 38 steers versus:	r
Daily gain on test	−0.259
Chilled carcass weight	+0.192
Chilled carcass weight per day of age	+0.209
Carcass grade	−0.029
Estimated fat in carcass	+0.166
Estimated marbling	+0.086
Ether extract of 9–10–11 rib	−0.149
Juiciness scores of broiled loin	−0.277
Juiciness scores of braised loin	−0.085
Tenderness scores of broiled loin	−0.061
Tenderness scores of braised loin	−0.081
Shear force values of broiled loin	+0.059
Shear force values of braised loin	+0.159

n=38 steers.
r=0.325 is required for significance at the 5% level.

to gain (growth) or to the fatness of the animal.[4] It also seemed possible that metabolic differences which produced different concentrations of thiamine in the muscles might also influence the juiciness or tenderness of the cooked meat. The coefficients of correlation between thiamine content and these possible sources of variation are given in table 5. None of these variables was significantly related to the thiamine content of longissimus dorsi.

Kunkel *et al.* (1952) have suggested that cytochrome oxidase activity of the liver may be indicative of the basal metabolic rate. Data for cytochrome oxidase activity had been obtained for some of these steers.[5]

[4] The production data were obtained by T. C. Cartwright, Associate Animal Husbandman and Geneticist, Substation No. 23, McGregor. The carcass data were obtained by O. D. Butler, Associate Professor, Department of Animal Husbandry, College Station.

[5] The data on cytochrome oxidase activity were obtained by Mary Futrell in the laboratory of H. O. Kunkel of the Department of Biochemistry. Dr. Kunkel graciously suggested their use in this comparison.

Correlation coefficients were calculated between thiamine content on the dry fat-free basis and the cytochrome oxidase activity in microliters of oxygen per milligram of liver tissue per hour. The coefficient was +0.351 for 13 of the 1954 steers and remained +0.351 after 5 more steers from the 1953 group were added. While these coefficients were not significant, they were higher than for any of the correlations in table 5.

Although the thiamine work was not undertaken primarily as a study in nutrition, placing the data in proper perspective from the point of view of practical nutrition may be advisable. Before cooking, one serving (125 gm. raw) of longissimus dorsi muscle from the 1954 steers would contain 0.108 mg. of thiamine if the steaks came from one breed and 0.120 mg. if they came from the other. Using the dietary allowance of 1.5 mg. of thiamine for 3000 Calories as recommended by the Food and Nutrition Board (1953), the percentages of the total daily allowance of thiamine supplied by these two breeds would be 7.2% and 8.0% respectively. This difference is too small to be of much practical value.

On the other hand, relating the thiamine content of meat to heriditary differences among animals may lead to a better understanding of metabolic processes. Inheritance studies with pigs, in which the thiamine content is high, might be especially rewarding if accurate control of the thiamine intake of each animal could be obtained.

Another possible relationship may be noted. The highest thiamine content occurred in the meat from the breed which had some Brahman blood. The Brahman breed has good heat tolerance, the physiological basis for which is under investigation at this station. If the thiamine requirement of animals increases under heat stress, as some workers believe, animals which normally carry larger stores of thiamine or have faster rates of absorption from the gastro-intestinal tract may be better equipped to withstand heat stress than those in which the storage is more limited or the rates of absorption are slower. In this connection, it is regrettable that samples from purebred Brahman steers were not available for this comparison. While any relationship between thiamine content of the meat and the heat tolerance of the animal is highly speculative at present, it is suggested as an interesting problem for further research.

Summary

Thiamine content was determined on the longissimus dorsi muscle of rib from 54 steers from known sires of two breeds. Half of them from each sire were fed a ration containing 35% concentrates and the others

70% concentrates. The thiamine content of the ribeye from animals on the two rations did not differ significantly. When the data for the two years were analyzed together the difference between breeds was highly significant, but the difference between sires within breeds was not significant. Simple correlations were not significant between thiamine content and each of the following: daily gain on test, chilled carcass weight, chilled carcass weight per day of age, carcass grade, estimated fat in carcass, estimated marbling, ether extract of trimmed 9–10–11 ribeye, juiciness scores of broiled loin or braised loin, tenderness scores of broiled loin or braised loin and shear force values of broiled loin or braised loin.

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RELATIONSHIPS BETWEEN CONFORMATION SCORES AND LIVE ANIMAL MEASUREMENTS OF BEEF CATTLE [1]

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THE objectivity of live animal measurements has appealed to many investigators as a means of describing the size and shape of farm animals. Several combinations of measurements have been proposed as indicators of conformation or slaughter and carcass grades.

The statement of Lush (1928) who said, "In the geometrical sense the animal body is of such a complicated shape that any one or few measurements could approximate a description of it in only the crudest way" seems appropriate in considering this problem. Evaluation on the basis of measurment does, however, have the advantages of (1) being independent of human judgment, and (2) remaining standard over long periods of time in contrast to subjective conformation and type standards which can and probably do change with time.

For these reasons body measurements are being taken routinely in several long-time beef cattle breeding projects. It is of interest to determine the relationships of some of the measurements most often being taken and the visual evaluation of type or conformation being made concurrently. The emphasis on a certain measurement could be intentional on the part of persons doing the scoring. It is also possible that optical illusions and/or failures of the human eye to properly evaluate various dimensions independent of size and condition may lead even experienced judges to unwittingly emphasize some body proportions not usually considered important.

Materials and Methods

The material for this study came from routine measurements being made on Angus and Hereford cattle at the Arkansas, Tennessee, Maryland, and North Carolina Agricultural Experiment Stations as part of the work of the S-10, Southern Regional Beef Cattle Breeding Project.

At the Arkansas station growing animals were measured near the standard ages of eight and twelve months with the deviation from the

[1] A publication of the Southern Regional Beef Cattle Breeding Project, S–10.

standard ages being no greater than 15 days in any case. Similar procedures were used at the Maryland and North Carolina stations with data from measurements at 6, 12, and 24 months being used. At these three stations measurements were made with calipers or tape according to standard procedures with length of body being measured from the anterior edge of the shoulder point to the posterior edge of the pin bone. Wither height, chest depth, and chest height were measured in the plane of the heart girth, just back of the front leg. Wither height was measured from the top of the shoulders to the ground. Chest depth was measured from the same point to the floor of the chest and chest height from the floor of the chest to the ground. Width measurements were secured at two stations. At Arkansas the widths given are averages of two figures—width at widest part of shoulder and width of hooks. Those for the North Carolina groups are averages of three figures—width at widest part of shoulder, width of hooks and width of pin bones. The "round measurement" used at Maryland was taken with a tape from patella to patella around the buttocks of the animals as described by Gregory (1933).

At the Tennessee station measurements are taken at times of changes in management such as weaning or when animals go from grass to winter feed, etc., rather than at specific ages. Thus, the animals within groups were more variable in age than at the other three stations. Measurements at the Tennessee Station were made from photographs taken under standard conditions back of a grid in a special chute. These have been shown (Smith *et al.*, 1950) to be at least as repeatable as measurements on live animals themselves.

At each station animals were scored for conformation by a committee of two or more persons working independently at or near the time of measurement. Personnel of the station reporting the data made up the committee at that station. The scores used in this study were the average scores given by the respective committees. Scoring systems, average scores, and standard deviations are given in table 2. This material is included since it roughly describes the cattle and gives the reader a general basis for interpreting the standard partial regression coefficients in terms of actual units of measurement. Sub-group means and variances have not been tested for heterogeneity but it is probable that significant differences exist in some cases.

Cattle at each station were maintained under management and nutritional regimes adequate for growth and development but there were wide differences between stations in feeds used, types of pasture, etc.

All data were analyzed on a within breed and sex basis with year to year differences also being removed in the Arkansas and Tennessee data. Variances and co-variances of sub-groups of like ages at a single station were pooled and the figures treated as having come from a single group in subsequent analyses. Comparisons of sub-group correlations within groups showed differences to be significant only about once in twenty cases or roughly the proportion of the time differences would be expected by chance at a probability level of 5% if all samples were from the same populations. Thus, pooling was considered to be justifiable.

Standard methods were used for the calculation of all statistics. For averaging or testing the significance of differences, correlation coefficients of the various groups were transformed to z. The abbreviated Doolittle technique for solving simultaneous equations was used for the calculation of standard partial regression and multiple correlation coefficients.

Results and Discussion

Table 1 gives simple correlation coefficients among the items studied. These correlations indicate a tendency for the judges to favor cattle that are heavy, deep and wide in body, and full in the round. They penalized cattle high off the ground at the chest floor. Correlations of height of withers and body length with score were, in general, numerically small. In spite of many significant relationships, however, the values of the coefficients of determination (r^2) indicating the percentage of the variance in type scores accounted for by the measurement concerned all are low—the highest average correlation between any measurement and score was +.34, indicating that weight differences in the older cattle account for only 11.5% of the variance in type score. It appears that the various measurements considered singly are of only limited usefulness in predicting type scores.

Working with weight-constant (900 lb. liveweight) populations of Milking Shorthorn and Beef Shorthorn slaughter steers Cook *et al.* (1951) and Yao *et al.* (1953) found correlations of —.19 to —.40 between wither height and slaughter grade, —.04 to —.51 between chest height and slaughter grade, —.08 to +.16 between shoulder width and slaughter grade, and —.16 to +.02 between body length and slaughter grade. White and Green (1952) found positive correlation between several live-animal measurements and slaughter grades in a group of 50 slaughter steers with the figure of +.48 between width of loin and

slaughter grade being the highest found. Kidwell (1955) noted the correlation of +.56 between slaughter grade and chest width to be the highest calculated from a group of measurements collected from

TABLE 1. CORRELATION COEFFICIENTS AMONG ITEMS STUDIED

(See table 2 for number of animals in each group)

Items	Group	Wither height	Chest depth	Chest height	Body length	Av. width	Circ. round	Score
Weight	Ark. calves	.63**	.78**	.29**	.66**	.79**		.24**
	Tenn. ♀ calves	.84**	.92**	.73**	.92**			.30*
	Md. calves	.65**	.73**	.26	.72**		.78**	.37**
	N. Car. ♀ calves	.59**	.61**	−.04	.65**	.47**		.18
	N. Car. ♂ calves	.89*	.80**	.27	.80**	.82**		.36
	Av. older cattle	.67**	.80**	.19**	.66**	.66**	.52**	.34[a]
Wither height	Ark. calves		.68**	.79**	.61**	.45**		−.04
	Tenn. ♀ calves		.84**	.80**	.82**			.15
	Md. calves		.85**	.76**	.75**		.61**	.27
	N. Car. ♀ calves		.32	.55**	.42*	.53**		−.21
	N. Car. ♂ calves		.61**	.56*	.83**	.88**		.09
	Av. older cattle		.69[a]	.75**	.56**	.38**	.37**	−.02
Chest depth	Ark. calves			.19**	.64**	.60**		.10
	Tenn. ♀ calves			.62**	.86**			.23
	Md. calves			.31	.83**		.76**	.47**
	N. Car. ♀ calves			−.60**	.32	.51**		.43*
	N. Car. ♂ calves			−.29	.65**	.60*		.52*
	Av. older cattle			.07	.60**	.68**	.36**	.29**
Chest height	Ark. calves				.33*	.15*		−.15*
	Tenn. ♀ calves				.68**			.09
	Md. calves				.33		.14	−.05
	N. Car. ♀ calves				.07	−.02		−.56**
	N. Car. ♂ calves				.38	.45		−.43
	Av. older cattle				.24**	.03	.16	−.31**
Body length	Ark. calves					.46**		.01
	Tenn. ♀ calves							.31*
	Md. calves						.74**	.25
	N. Car. ♀ calves					.31		.02
	N. Car. ♂ calves					.80**		.05
	Av. older cattle					.44**	.34**	.10
Width	Ark. calves							.28**
	N. Car. ♀ calves							.05
	N. Car. ♂ calves							.19
	Av. older cattle							.26*
Round circ.	Md. calves							.30
	Av. older cattle							.27**

[a] Differences among group correlations averaged to get these figures were highly significant (P=.01). * P=.05, ** P=.01.

64 Hereford show steers. Our correlations are consistent with those previously reported in that numerical values are relatively low and of only limited predictive value.

The next phase of the study involved the use of multiple regression techniques. Table 2 gives data on averages and variability of the groups used. Table 3 gives standard partial regression coefficients of conformation score on the items studied and multiple correlations for each of

TABLE 2. MEANS AND WITHIN-SUBGROUP STANDARD DEVIATIONS OF WEIGHTS, BODY MEASUREMENTS, AND SCORES BY GROUPS

	Arkansas calves (8 mo.)		Tennessee heifer calves (weaning)		Maryland heifer calves (6 mo.)		Maryland steer calves (6 mo.)		North Car. Heifer calves (6 mo.)		North Car. bull calves (6 mo.)	
No. animals	221		48		32		34		31		17	
No. subgroups	16		4		2		2		2		1	
	Mean.	St. Dev.	Mean.	St. Dev.	Mean.	St. Dev.	Mean.	St. Dev.	Mean.	St. Dev.	Mean.	St. Dev.
Weight, lb.	477	65.6	383	89.5	336	49.4	358	45.5	372	38.4	420	56.7
Wither ht., in.	37.6	1.6	37.6	6.0	34.9	4.1	36.3	4.1	35.3	2.2	36.1	3.2
Chest depth, in.	19.5	.9	20.0	3.6	18.4	3.0	18.8	2.6	18.7	2.3	19.1	2.8
Chest height, in.	18.2	1.1	17.4	2.6	16.5	2.3	17.5	2.2	16.6	2.5	17.0	2.6
Body length, in.	46.6	2.1	41.2	7.9	40.2	8.3	41.0	5.5	41.3	4.0	41.9	6.2
Av. width, in.	13.9	1.1	....	...	....	...	....	...	10.0	2.1	10.7	2.0
Round circ., in	....	...	....	...	28.4	7.0	29.8	5.1	....	...	....	...
Scores[a]	68.8	5.6	12.2	1.2	11.5	2.1	11.2	1.6	11.4	1.5	11.1	1.6

	Arkansas heifers (12 mo.)		Maryland heifers (12 mo.)		Maryland steers (12 mo.)		Tennessee steers (yearling)		Tennessee heifers (long yr. & 2 year old)		Maryland heifers (24 mo.)		Tennessee cows (mature)	
No. animals	96		39		40		29		43		25		70	
No. subgroups	8		2		2		2		3		2		3	
	Mean.	St. Dev.	Mean.	St. Dev.	Mean.	St. Dev.	Mean.	St. Dev.	Mean.	St. Dev.	Mean.	St. Dev.	Mean.	St. Dev.
Weight, lb.	546	62.9	640	96.3	721	90.5	665	79.4	774	115.3	967	69.3	1004	72.7
Wither ht., in.	39.6	1.6	39.5	3.9	41.3	3.6	43.0	4.0	43.2	4.1	44.2	3.0	45.6	2.3
Chest depth, in.	20.8	.9	22.0	2.8	22.8	2.8	22.9	2.6	23.5	2.9	25.9	1.6	25.9	1.9
Chest height, in.	18.8	2.1	17.5	2.2	18.5	3.3	20.1	2.9	19.7	2.6	18.3	2.8	19.8	1.6
Body length, in.	48.6	1.3	47.0	5.6	48.3	6.6	48.3	4.4	50.0	6.3	53.5	3.9	54.3	4.1
Av. width, in.	14.3	1.2	....	...	....	...	....	...	....	...	....	...	....	...
Round circ., in.	....	...	32.5	5.9	33.7	6.1	....	...	....	...	36.0	6.7	....	...
Scores[a]	69.7	5.7	10.3	3.1	11.1	2.1	11.3	1.0	11.9	1.2	11.3	2.4	11.9	.8

[a] Arkansas scores are on a scale ranging from 30 to 100. All other scores are on a scale with 6–8=medium; 9–11=good; 12–14=choice; and 15–17=fancy.

TABLE 3. RELATIONSHIP OF BODY MEASUREMENTS TO CONFORMATION SCORES AMONG GROUPS OF BEEF CATTLE AT FOUR DIFFERENT EXPERIMENT STATIONS

Group[a] designation	Weight (lb.)		Wither ht. (in.)		Chest depth (in.)	Chest ht. (in.)	Body length (in.)		Av. width (in.)		Circ. rnd. (in.)		Using b_1		Using b_2	
	b_1	b_2	b_1	b_2	b_2	b_2	b_1	b_2	b_1	b_2	b_1	b_2	R	$(1-R^2)$	R	$(1-R^2)$
Ark. calves	.34**	.40**	—.04	.18	.18	1.6*	—.15	.20**	.19	.17	...	...	.38**	.86	.39**	.85
Tenn. ♀ calves	.36	.77	—.41	—.49	—.49	—.34	.31	.25	...	...	...	...	.38	.86	.41	.83
Md. ♀ calves	.64	.70*	—.45	.32	.32	—.45*	—.20	—.44	...	...	.26	—.13	.54*	.71	.64*	.59
Md. ♂ calves	.14	.09	.47	.74*	.74*	.06	—.10	—.30	...	...	0	—.09	.50*	.75	.56*	.68
N. Car. ♀ calves	.51	.20	—.52	.04	.04	—.53	—.13	—.07	.12	—.05	...	...	.45	.80	.59*	.66
N. Car. ♂ calves	1.39	.92	—1.15	—.34	—.37	—.79	—.44	—.46	.42	.38	...	...	.67*	.54	.72*	.48
Ark. ♀ 12 mo.	.54**	.57**	—.42**	—.33**	—.33	—.18*	—.19*	—.28**	.14	.20*	...	...	.48**	.77	.49**	.76
Md. ♀ 12 mo.	.72**	.48	—.13	.23	.23	—.22	.03	—.01	...	...	—.02	.04	.64**	.59	.74**	.54
Md. ♂ 12 mo.	.20	—.08	—.30	.41	.41	—.43**	.20	—.04	...	...	.20	.14	.42	.83	.66**	.56
Tenn. ♂ yrlng.	.79*	.39	—.25	.35	.35	—.28	—.32	—.28	...	...	...	...	.50*	.75	.61*	.63
Tenn. ♀ 2 yr. old	.97**	.67*	—.51**	—.03	—.03	—.45**	—.02	—.01	...	...	...	...	.72**	.48	.76**	.42
Md. ♀ 24 mo.	.01	.08	—.46	—.35	—.35	—.44	—.01	.02	...	...	.42	.42	.50	.75	.50	.75
Tenn. ♀ cows	1.03	.83**	—.69**	—.31	—.31	—.43**	—.41*	—.37	...	...	...	...	.55**	.69	.56**	.68

[a] See table 2 for number of animals per group and number sub-groups.

b_1 Standard partial regression coefficient of score on items given when wither height is included as an independent variable.

b_2 Standard partial regression coefficient of score on items given when chest depth and chest height are included as independent variables.

* P=.05, ** P=.01.

the groups. Although wither height, chest depth and chest height are usually thought of as independent items in livestock judging, the fact that chest depth plus chest height is wither height implies statistical dependencies among the three measures. Therefore, two separate analyses were run, one including only wither height and the other including chest height and chest depth. The results are shown separately in table 3. The standard partial regression coefficients indicate the fraction of a unit (standard deviation) change in the dependent variable (score in this case) for each unit (standard deviation) change in the particular variable being considered independent of other variables. The multiple correlation measures the joint influence of all other items on score with its square (R^2) indicating the percent of the variance in score accounted for by a knowledge of all the other variables. The figures ($1-R^2$) near the right hand side of the table indicate the percent of the variance in score not accounted for by the measurements. In a somewhat similar study Yao *et al.* (1953) found a multiple correlation of .48 between slaughter grade and chest height, rump length and circumference at navel, in a weight-constant population of 900 lb. steers.

In nine of the thirteen groups the multiple correlation coefficients were significant ($p=.05$ or less) regardless of whether wither height or chest depth and chest height were used in its calculation. In two other groups one multiple correlation was significant while in two groups neither was significant. The multiple correlations indicate that the linear effects of weight and the various body measurements considered jointly account for from 14 to 58% of the variance in conformation scores. One or the other or both of the multiple correlations was large enough in seven of the thirteen groups to account for more than one-third of the variance in scores. In two groups one of them was large enough to account for more than half the variance in scores. From 42 to 86% of the variance in scores is not accounted for by the multiple correlations and must depend upon other items seen by the judges but not reflected in weight or the body measurements studied, inability of the judges to "see" the items measured, errors of judgment in scoring, or errors in weighing and measuring the animals. Further, the methods of analysis used would not detect curvilinear relationships between the items measured and conformation score.

Although, as can be seen from table 3, the values of the standard partial regression coefficients are quite variable from group to group, certain trends are present. The standard partial regressions of score on weight are positive in all except one case and in 14 instances have numerical values of .50 or higher. Apparently most scorers consciously

or unconsciously gave weight considerable importance in arriving at a score. The regression of score on chest height was negative in 11 of 13 cases and that of score on wither height was negative in 12 of 13 cases. Although only a few of these coefficients are statistically significant their consistency suggests that scorers considered these factors to be of importance independent of other considerations in arriving at scores. Coefficients involving body length were also predominantly negative. Width measurements had positive coefficients in most cases where they were available but were significant in only one case. Coefficients involving chest depth and round measurement were variable from group to group indicating no general trend.

In addition to the multiple regression statistics, simple correlations were calculated between scores and a number of ratios involving two or more measurements. In only a few cases were they higher than multiple correlations involving the same items. Simple correlations involving one of the items in some cases were higher than those involving a ratio of it with another.

The ratio $\frac{\text{Body weight}}{\text{Wither height}}$ was proposed by Knapp and Cook (1933) as a measure of beef type and was later shown by Black *et al.* (1938) to be highly related ($r=+.84$) to slaughter grade in a group of 50 steers slaughtered at 900 lb. Lush (1928) found a correlation of $+.56$ between the ratio $\frac{\text{Heart girth}}{\text{Wither height}}$ and estimated fatness. Since heart girth is highly related to live weight (Johannson and Hildeman, 1954) these ratios should be highly related. In our data the ratio $\frac{\text{Body weight}}{\text{Wither height}}$ was positively related to type score in 12 of 13 groups and averaged $+.38$ in calves and $+.42$ in older cattle. Whether this relationship is an indirect one due to possible influence of fatness on conformation score or whether it is a true reflection of type as seen by the scorers is unknown.

The ratios $\frac{\text{Chest depth}}{\text{Wither height}}$ and $\frac{\text{Chest depth}}{\text{Chest height}}$ should have quite similar relationships to score and should be nearly independent of fatness since they involve items reflecting skeletal dimensions more than fatness (Lush, 1928; and earlier Missouri work). They are probably not entirely free of the influence of fatness since Hultz (1927) and Hultz and Wheeler (1927) observed changes in the ratio $\frac{\text{Chest depth}}{\text{Wither height}}$ during fattening, with chest depth increasing more than height. In these data,

both ratios are positively related to conformation in all groups with the correlations averaging +.31 and +.30 in calves and +.42 and +.49 in older cattle. Although neither of these ratios account for more than 35% of the variance in score in only a few groups, they may be useful as partial evaluations of conformation.

The ratio $\frac{\text{Chest depth}}{\text{Body length}}$ was related less consistently to score than either of the preceding. The ratio $\frac{\text{Chest depth}}{\text{Wither height} \times \text{Body length}}$ was investigated but had little relationship to scores. The ratio $\frac{\text{Round measurement}}{\text{Wither height}}$ was suggested by Gregory (1933) as an index of beef type and found by Guilbert and Gregory (1952) to the "highly correlated with grade" in the California Station Hereford herd. Correlations between this ratio and score were positive in four of five groups of Maryland cattle where the round measurement had been made. The correlations in four cases, however, were lower than correlations between other ratios and scores.

These studies involving data from several sources and scores by several men are in general consistent with earlier studies in indicating statistically significant relationships between certain body measurements and conformation scores. They are also consistent with other studies in indicating that no measurement or combination of measurements has a high predictive value in determining score. The rather consistent positive relationship between weight and score both grossly and independent of other measurements is at variance with the commonly held viewpoint that small cattle are favored in type evaluation.

The existence of significant differences in many instances between stations and between groups of cattle in the strength of relationships between scores and body measurements makes it seem inadvisable to attempt to formulate specific indexes at this time for application to cattle in general. Presumably these differences result from different standards in the minds of persons doing the scoring at various locations.

The body measurements studied were imperfect indicators of scores, but scores at a given time are also imperfect indicators of permanent conformation ratings. Studies at the Arkansas and Georgia stations (Gifford *et al.*, 1951 and unpublished Georgia data) indicate that animal differences account for 75% or more of the variance in average scores given by a group of competent men at a given time, but that repeated scoring by the same men at intervals of several months re-

duces the animal component of the variance to around 50%. In other words, competent judges tend to agree on the evaluation of an animal at a given time but must all be influenced more or less alike by temporary factors such as age, degree of finish, etc.

Few data are available on the repeatability of the ratios of body measures shown to be related to conformation. If further work should show such ratios to be more permanently characteristic of a given animal than is score, then the value of measurements in long time breeding programs would be apparent.

Summary

Conformation scores given to 383 calves and 342 older beef cattle of the Angus and Hereford breeds at four experiment stations were studied in relation to body measurements. Simple correlations varied significantly between groups of cattle in several instances. Average correlations between scores and weight, chest depth, body width, and fullness of round were positive but of limited predictive value. Correlations between chest height and score were negative while wither height and body length were not consistently related to scores.

Multiple correlations between all the measurements studied and conformation scores varied from .38 to .76 for the various groups, thus accounting for from 14 to 58% of the variance in scores. Standard partial regression coefficients, measuring the influence of each measurement on score independent of other factors, indicated a rather consistent positive relationship of weight to score. Negative relationships were observed between score and chest height, wither height and body length. Width measurements were not available on all cattle but those available tended to have a positive relationship with score. Other measurements were inconsistent.

Simple correlations between conformation scores and several ratios of measurements indicated that the ratios $\frac{\text{Chest depth}}{\text{Wither height}}$ and $\frac{\text{Chest depth}}{\text{Chest height}}$ were rather consistently positively related to scores with actual correlations ranging from +.15 to +.81 for different groups of animals.

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ENVIRONMENTAL FACTORS AFFECTING BODY DIMENSIONS IN YEARLING HAMPSHIRE EWES

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IN the mutton breeds of sheep, growth rate, or size at a given time in the life of an animal, and conformation, or the body shape which an animal attains, are important selection criteria used by most breeders. Methods of measuring these characteristics in practical situations are not usually objective and are subject to error and inconsistencies because of differences among observers. Environmental factors affecting the animals are also important sources of variation.

Admittedly, size and conformation are complex characteristics, and no satisfactory practical method for reducing them to a single numerical rating has been found. However, measurements (taken with instruments) such as those with which this paper deals, offer certain advantages. They may be taken with reasonable accuracy and consistency at different times and by different operators. These advantages seem to make it worth while to try to find some way to use measurements in selection of animals, although the exploitation of this possibility may require much further work. One possible step toward improving accuracy is to estimate the effects of various factors which influence the growth of animals, and to use these estimates to eliminate sources of variation in observations, thus making comparisons more critical. The present paper reports the results of estimating the effects of (1) differences in age, (2) percent inbreeding, (3) being the offspring of a 2-year-old versus a mature dam, and (4) being born a twin versus a single, on the body measurements of Hampshire yearling ewes. In a previous paper (Cassard *et al.*, 1953) it was shown that in the environment at Davis, California, body measurements of Rambouillet yearling ewes (except withers height) were significantly affected by age differences.

In studies involving body weight, other workers have obtained similar results with several breeds under different environmental conditions (Hazel and Terrill, 1946; Terrill *et al.*, 1947), although the magnitudes of estimates differed. A study of body conformation of Rambouillet yearling ewes as measured by ratios of body measurements has been reported by Cassard *et al.* (1954). Working with Rambouillet yearling

ewes, Hazel and Terrill (1946) found that type scores (primarily a rating of body conformation) of singles were higher than those of twins.

Experimental

Measurements taken just after shearing in each of the 17 years ending with 1954, on a total of 227 yearling Hampshire ewes furnished the data for the present study. These ewes were born mostly in December and January, weaned at 4 to 5 months of age, and grazed on barley stubble or irrigated pasture in one band with little if any supplement during the summer and fall. They were fed hay during the winter and shorn usually about the first week in April, at which time measurements were taken. No selection was practiced up to this time. Thus, except for the usual death losses, all animals born were measured.

Body weight was taken on a normal fill to the nearest pound; heart girth and round measurements were taken with a corded linen tape to the nearest centimeter. Withers height was taken with a special measuring standard and chest width, chest depth and loin width with calipers designed for this purpose, all to the nearest centimeter. In any given year, all measurements were taken by the same person. Number of ewes measured varied from 3 to 26 per year, with an average of 13.4. Data were classified according to birth as a twin or as a single. For the various years the proportion of twins ranged from .286 to .846 but averaged .593. Proportion of ewes born to 2-year-old dams as opposed to older ones ranged from .158 to .667 with a mean of .350. Inbreeding coefficients of ewes born in the same year averaged from .000 to .227, with a gross mean for all animals of .0341. Age at the time of measurement averaged 440 days.

Eighteen sires were used in the period studied. One was in use over a period of 5 years; two for 3 years; four for 2 years, and the rest for 1 year only. In five of the years there were progeny of only one sire available. Thus since different sires or combinations of sires were usually in use in different years the effects of sires and years are not separable.

The data were analyzed by the method of fitting constants suggested by Yates (1934) for the analysis of multiple classifications with disproportionate subclass numbers, except that it was extended to include age at measurement time and percent inbreeding as independent variables as suggested by Hazel (1946). Thus, least squares estimates were obtained of the regression of each measurement on age in days, and on percent inbreeding, the effect of being born a twin or a single, and the

TABLE 1. ESTIMATES OF ENVIRONMENTAL EFFECTS ON BODY MEASUREMENTS

Measurements:	Regression on age in days	Regression on percent inbreeding	Single minus twin	Mature minus 2-year-old dam	Adjusted mean	Within-years standard deviation
Body weight, lb.	.2127**	—.5819**	8.2**	—0.3	124.42	12.73
Heart girth, cm.	.0634**	—.1968**	1.7**	0.5	88.01	3.82
Round measurement, cm.	.0362**	—.0819**	1.4**	—0.1	51.66	2.39
Withers height, cm.	.0100	—.0417	1.1**	0.1	60.52	2.27
Chest depth, cm.	.0176**	—.0660**	0.2	0.2	28.11	1.28
Chest width, cm.	.0168**	—.0590**	0.7**	0.1	22.19	1.44
Loin width, cm.	.0147**	—.0373**	0.3*	—0.0	14.17	0.95
Ratios:						
$\frac{\text{Heart girth}}{\text{Withers height}}$	.0008**	—.0002	0.0049	0.0174	1.4428	0.0653
$\frac{\text{Chest depth}}{\text{Withers height}}$	.0002**	—.0008**	—0.0048	0.0025	0.4688	0.0230
$\frac{\text{Chest width}}{\text{Heart girth}}$	.0000	—.0001	0.0030	—0.0003	0.2499	0.0098
$\frac{\text{Chest width}}{\text{Chest depth}}$	.0001	—.0003	0.0192**	—0.0010	0.7856	0.0457

* Indicates significance at the 5% level.
** Indicates significance at the 1% level.

effect of being the offspring of a 2-year-old dam or an older one. The 17 year-effects were also included, with the idea of increasing the accuracy of the other estimates, although these year-effects cannot be separated from those of sires or of different observers, and thus have not been used in adjusting the data.

Results

The results of this analysis are shown in table 1. A check on the interaction between the effects of type of birth and age of dam revealed none in any of the measurements in this study. This is in contrast to the results of the Rambouillet study in which the twin offspring of 2-year-old dams were smaller than other twins in body weight, heart girth, and round measurement, whereas singles were not affected by dam age.

Measurements

Body Weight. Older animals were heavier than younger ones by .2127 lb. per day difference in age. Inbred animals were lighter in weight than those less inbred by .5819 lb. for each 1% difference in inbreeding coefficient. Singles were heavier than twins by 8.2 lb. Age-of-dam effect as estimated here was not significantly different from zero at the 5% level.

Heart Girth. Older animals were .0634 cm. larger than younger ones for each day difference in age. Those more inbred were smaller in heart girth than those less inbred by .1968 cm. for each 1% difference in their inbreeding coefficients. Singles were 1.7 cm. larger than twins, but the offspring of 2-year-old dams were not significantly different from others in this measurement.

Round Measurement. In this measurement, regression on age in days was .0362 cm. per day difference in age at measurement time. Each percent increase in the inbreeding coefficient corresponded to a .0819 cm. smaller round measurement. Singles exceeded twins by 1.4 cm. Age of dam had no appreciable effect.

Withers Height. Neither the regression of withers height on age or that on percent inbreeding was large enough to be significant. However, singles were 1.1 cm. taller at the withers than twins.

Chest Depth. This measurement was significantly affected by differences in age (.0176 cm. per day) and inbreeding (—.0660 cm. per 1% increase) but twins were not greatly different from singles nor were the two dam-age classes significantly different.

Chest Width. Older animals were wider in the chest than younger ones by .0168 cm. for each day difference in age while more inbred animals were narrower by .0590 cm. per percent difference in inbreeding coefficient than those less inbred. Singles were 0.7 cm. wider than twins, but the difference due to age of dam was not large enough to be significant.

Loin Width. Age of dam made no difference in this measurement, but singles were 0.3 cm. wider across the loin than twins and the regressions on age and percent inbreeding were .0147 and —.0373 respectively, both being significant.

Ratios of Measurements

In order to find whether the effects estimated were important in determining shape or conformation, as well as body size, the following simple ratios were calculated for each animal included in the study, and the same effects estimated as for the individual measurements: heart girths and chest depth, respectively, to withers height; chest width to heart girth; and chest width to chest depth. The results are given in table 1.

Heart Girth/Withers Height. Older animals were larger in their heart girths in proportion to height by .0008 per day age difference. Other effects estimated did not make an appreciable difference in this aspect of body shape.

Chest Depth/Withers Height. In this ratio, older animals were relatively deeper than younger ones by .0002. Less inbred animals were .0008 higher in this ratio per percent difference in inbreeding coefficient than more inbred ones. Type of birth and age of dam did not significantly affect this measurement ratio.

Chest Width/Heart Girth. None of the effects studied made significant differences in this ratio.

Chest Width/Chest Depth. This is perhaps a more critical way to measure the shape of the chest than the one above. It was found that in this ratio, singles were higher than twins. Thus singles are wider in relation to their depth of chest at yearling age than twins. Other effects were not significant on this ratio.

Using the estimates obtained from the various effects as correction factors, the data for measurements and ratios were adjusted to a single, non-inbred basis and to the average age of 440 days. No adjustment was necessary in any of the measurements for age of dam. An overall average for the adjusted data in each measurement was then

calculated as well as a within-years standard deviation. These are reported for each measurement in the last two columns of table 1.

Discussion

The results reported here show that the effects estimated are important in determining the variation observed in the body size and conformation of Hampshire yearling ewes. Where comparable, the effects seem similar to those reported in other studies along these lines although magnitudes of effects differ.

It is interesting to compare the estimates obtained in this study with those in the Rambouillets raised in the same environment (Cassard *et al.*, 1953, 1954). The difference in conformation between the two breeds is brought out by comparing the adjusted means of measurements. Hampshires average about 6 lb. heavier at this age, and are 2.9 cm. larger in heart girth, 2.74 cm. larger in round measurement, 0.8 cm. wider across the loin, and 1.5 cm. wider in the chest. However, the Rambouillets are 1.4 cm. deeper in their chests and 6.4 cm. taller at the withers. Hampshires averaged higher in the ratios of heart girth to withers height and chest width to chest depth.

The estimates of the regression of age on the measurements are not greatly different for the two breeds in body weight, heart girth, round measurement, and loin width. Estimates are considerably lower for Hampshires than Rambouillets in chest width and depth. Apparently both breeds end their growth in height before this age, as the regression of age on withers height was not significant for either. In Rambouillets, age of dam affected twins for weight, heart girth, and round, and in some of the measurement ratios. It seems not to affect Hampshires of the age range in this study.

In general, the difference between singles and twins seems to be greater in Rambouillets than Hampshires. However, in heart girth and round measurement where there is a significant difference between the two birth types in Hampshires, there was none in Rambouillets after the effect of 2-year-old dams on twins was removed. The presence of interaction in the Rambouillet data undoubtedly affects this comparison. It should be noted that the average age of Hampshires at shearing was 440 days as against 475 days for the Rambouillets.

In general it would seem that the effects estimated here are somewhat less severe on Hampshires than on Rambouillets. This may be partly due to the fact that since Hampshire ewes milk more heavily than

Rambouillets; the Hampshire lambs in their early life are on a somewhat higher plane of nutrition.

The estimates reported here for Hampshire ewes show that these effects are important in determining both body size and conformation. They help explain why twins or inbred animals may be rated lower on their appearance than singles or non-inbred animals and why younger animals may be rated lower than older ones although both are in the yearling age range. That twins may be given lower type scores than singles was demonstrated by Hazel and Terrill (1946). Phillips and Dawson (1940) reported that higher proportions of early lambs than late and of singles than twins were selected for breeding. Presumably some of the same differences are involved in these studies as in the present ones.

Summary

Body measurements and simple ratios of these measurements taken on yearling ewes from the University of California Hampshire sheep flock over a period of 17 years, were studied to learn the importance of certain known environmental differences in determining body size and conformation.

In the group studied, older animals were found to be significantly larger than younger ones in body weight, heart girth, round measurement, chest width and depth, loin width and in the ratio of heart girth to withers height and chest depth to withers height, but not in withers height or the ratios of chest width to heart girth or chest depth.

More-inbred animals were smaller than less-inbred ones in weight, heart girth, round measurement, chest depth and width, loin width and in the ratio of chest depth to withers height, but not in withers height or other ratios.

Singles were larger than twins in all individual measurements studied except chest depth. Singles were higher than twins in the ratio of chest width to depth but not in other ratios.

The offspring of 2-year-old dams were not significantly different from others in any of the measurements or ratios studied.

Data were adjusted to single, non-inbred status and to the average age of 440 days, using the estimates calculated. The means and within-years standard deviations for these data are also reported.

It is concluded that both body size and conformation are affected to an important extent by the factors studied.

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PREDICTION EQUATIONS FOR ROTATIONAL CROSSBREEDING [1]

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ROTATIONAL crossbreeding was first suggested by Winters (1935) and in recent years has been used increasingly for capitalizing on the hybrid vigor from breed or line crosses. This system of breeding allows for the retention of crossbred females as parents and thus takes advantage of any hybrid vigor for traits which are more dependent on the genotype of dam than on the individual's own genotype. Data from Lush *et al.* (1940), Winters (1935, 1952), Robison (1948) and England and Winters (1953) indicate that hybrid vigor can be expected from the rotation of two or three breeds of swine.

Rotational breeding is a long-time program and the breeder needs some basis for choosing the breeds or lines and the order of rotation for maximum performance. Thus, it would be of value to have equations for predicting the performance of a series of potential rotations from data obtainable without actually testing each rotation.

Wright (1922) gave an equation for predicting F_2 yield from performance of parent lines and their single-crosses. For this method Neal (1935) found very close agreement between predicted and observed values in corn. Jenkins (1934) found, out of four methods for predicting the performance of double-crosses in corn, the best method to be the mean of four of the six possible single-crosses excluding the two single-cross parents of the double-cross.

In this study equations are derived for predicting the performance of rotations from the performance of the parent lines or breeds and their single-crosses.

Procedure

The expected phenotypic mean is derived for the following breeding systems: (1) random mating, (2) single-crosses, (3) double-crosses and (4) rotational crossbreeding involving two, three and four lines.

[1] Prepared from a portion of a thesis submitted by J. L. Carmon in partial fulfillment of requirements for the degree of Doctor of Philosophy in Animal Industry at North Carolina State College.

[2] Present address is Assistant Professor of Animal Husbandry, University of Georgia, Athens, Georgia.

[3] Animal Industry Department. Published with the approval of the Director of Research as Paper No. 705 of the Journal Series.

Procedure in connection with the rotational system may be illustrated in terms of a three line or breed rotation where the lines are designated as *i*, *j* and *k*. Let i_n symbolize the n-th generation produced using line *i* as the male parent and let $\bar{i}_n$ symbolize the mean performance in the generation. Expressions were derived for $\bar{i}_n$, $\bar{j}_n$ and $\bar{k}_n$. The limits approached by these three expressions as *n* becomes very large were then averaged to obtain the average limiting value of the expected phenotypic mean for that rotation. It should also be noted that the treatment assumed all members of each generation out of dams of the preceding generation, i.e. no holding over of dams that would lead to variations in pedigree.

The following assumptions were made relative to the mode of inheritance: (1) diploid behavior at meiosis, (2) two alleles per locus and (3) no interaction of non-allelic genes. It is further assumed that gametes as well as zygotes have equal viabilities, that the parent lines or breeds do not change in gene frequencies and that sires and dams are random members from their respective populations. The effects of relaxing some of these assumptions will be discussed later.

Results and Discussion

(a) Expressions for the expected phenotypic means.

It is sufficient to consider the effects at one locus since, without interaction of non-allelic genes, the average effects of the genotypes at any

TABLE 1. THE DISTRIBUTION OF GENOTYPES AND PHENOTYPIC VALUES FOR A RANDOM MATING POPULATION

Genotype	Frequency	Average Phenotype	Y
BB	p^2	z+2u	2u
Bb	2p(1—p)	z+u+au	u+au
bb	$(1-p)^2$	z	0

one locus are independent of the genotype for other loci. Thus, expressions for a single locus may be simply summed over all loci to obtain expressions reflecting the effect of the entire genotype. The distribution of genotypes for one locus and the corresponding phenotypic values in a random mating population are shown in Table 1.

The coded values of the average phenotype are listed under *Y*. Note that *u* is half the difference in average phenotypic value between BB and bb and *a* reflects the degree of dominance. *a* can vary from zero,

no dominance, to one, complete dominance and also beyond one, over-dominance. p is the population frequency of the gene B.

The expected mean phenotypic value for a single given locus in a line or breed in which genotypic frequencies are in Hardy-Weinberg equilibrium is

$$\bar{Y}=2p^2u+2p(1-p)(u+au)$$

which reduces to

$$\bar{Y}=2u[p+ap(1-p)]. \tag{1}$$

The average performance of x breeds or lines is

$$\bar{X}_x=2u[\bar{p}+a\{\bar{p}(1-\bar{p})-\sigma_p^2\}]. \tag{2}$$

where $\bar{p}=\sum_{i=1}^{x}\frac{p_i}{x}$ and $\sigma_p^2=\sum_{i=1}^{x}\frac{(p_i-\bar{p})^2}{x}$

The expected phenotypic mean for the $\frac{x(x-1)}{2}$ single-crosses among x lines is

$$S_x=2u\left[\bar{p}+a\left\{\bar{p}(1-\bar{p})+\frac{\sigma_p^2}{x-1}\right\}\right]. \tag{3}$$

When x equals 2 so that only one single-cross is under consideration, (3) reduces to

$$S_2=2u[\bar{p}+a\{\bar{p}(1-\bar{p})+\sigma_p^2\}]. \tag{4}$$

The expected phenotypic mean for a double-cross, where the single-cross parents are $(i\times j)$ and $(k\times l)$, is

$$D=2u[\bar{p}+a\{\bar{p}(1-\bar{p})+\sigma_p^2-\tfrac{1}{2}(\beta_1^2+\beta_2^2)\}], \tag{5}$$

where $\beta_1=\frac{p_i-p_j}{2}$ and $\beta_2=\frac{p_k-p_l}{2}$.

For a two line rotation, the expected mean phenotypic value that is approached as the number of generations increases is found to be

$$R_2=2u[\bar{p}+a\{\bar{p}(1-\bar{p})+\tfrac{1}{3}\sigma_p^2\}]. \tag{6}$$

For a three line rotation, the limiting value of the average phenotypic mean is

$$R_3=2u[\bar{p}+a\{\bar{p}(1-\bar{p})+\tfrac{2}{7}\sigma_p^2\}]. \tag{7}$$

The order of rotation will not affect the expression of the phenotypic mean for a three line rotation because each line is adjacent to the other two lines and thus each of the initial rotations reaches the same composition after several cycles of rotation.

For a four line rotation in which lines are used as the source of sires

in the order, i, j, k, l, the mean approached as the number of generations increases is

$$R_4=2u[\bar{p}+a\{\bar{p}(1-\bar{p})+\tfrac{1}{5}\sigma_p^2+\tfrac{1}{120}(\Delta_1-\Delta_2)\}], \qquad (8)$$

where $\Delta_1=(p_i-p_j)^2+(p_i-p_l)^2+(p_j-p_k)^2+(p_k-p_l)^2$
and $\Delta_2=(p_i-p_k)^2+(p_j-p_l)^2$. The order of rotation affects the four line rotation as can be seen in the Δ's.

In the case of expressions (2) through (8) it is to be understood that $\bar{p}$ and σ_p^2 are in each case functions of the gene frequencies (p's) of just those lines from which the material in question originates, i.e. in the case of (3) $\bar{p}$ and σ_p^2 are functions of the p's for the x lines of which single-crosses are under consideration.

(b) The prediction equations.

The prediction equations are derived from expressions for phenotypic means listed above. Consider a two line rotation. From equations (2), (4) and (6)

$$S_2-\bar{X}_2=4au\sigma_p^2$$

and $$S_2-R_2=\tfrac{4}{3}au\sigma_p^2.$$

It follows that $$3(S_2-R_2)=S_2-\bar{X}_2$$

from which $$R_2=S_2-\frac{(S_2-\bar{X}_2)}{3}. \qquad (9)$$

The equality derived in (9), while not a prediction equation, provides a logical basis for writing the prediction equation by substituting estimates for the above parameters. A prediction equation based on (9) is obtained by replacement of R_2, S_2 and $\bar{X}_2$ with their estimates. Thus, the mean performance for a long-time two line rotational breeding program can be predicted as the average performance of the single-cross of the two lines minus one-third of the difference between the average of the single-cross and the average of mean performance in the two parental lines.

In the case of a three line rotation, we find from equation (2), (3) and (7)

$$S_3-\bar{X}_3=3au\sigma_p^2$$

and $$S_3-R_3=\tfrac{3}{7}au\sigma_p^2.$$

It follows that $$7(S_3-R_3)=S_3-\bar{X}_3$$

from which $$R_3=S_3-\frac{(S_3-\bar{X}_3)}{7}. \qquad (10)$$

If R_3, S_3 and $\bar{X}_3$ are replaced by their estimates, the prediction equation

for a three line rotation is obtained. Thus, performance in a long-time three line rotational program is predicted by the average performance of the three single-crosses possible among the three lines minus one-seventh of the difference between this single-cross average and the average performance of the three parental lines.

Performance in a four line rotation is a function of order of rotation (see equation 8), which we will assume to be *i, j, k, l*. Let S_{na} symbolize the average of the expected phenotypic means of the single-crosses, (i×k) and (k×l), i.e. the single-crosses possible among lines that are not adjacent in the rotation. It can be shown using equations (2) and (3) that

$$S_{na}-\bar{X}_4=4au(\sigma_p^2-\frac{\Delta_1}{16}+\frac{\Delta_2}{16})$$

and from equations (3) and (8)

$$S_4-R_4=\frac{4au}{15}(\sigma_p^2-\frac{\Delta_1}{16}+\frac{\Delta_2}{16}).$$

It follows that $15(S_4-R_4)=S_{na}-\bar{X}_4$

from which
$$R_4=S_4-\frac{(S_{na}-\bar{X}_4)}{15}. \qquad (11)$$

The prediction equation for a four line rotation is obtained by replacing R_4, S_4, S_{na} and $\bar{X}_4$ of (11) by their estimates. Thus, performance in a long-time four-line rotational program is predicted by average performance of the six single-crosses possible among the four lines minus one-fifteenth of the difference between the average performance of the two single-crosses of lines non-adjacent in the rotation and the average of the four parent lines.

An expression for performance in a random breeding population synthesized from x lines or breeds, each of which contribute equally, is obtained as follows: mean gene frequency at a particular locus in the derived population will be $\bar{p}$ so that the expected mean phenotypic effect $\bar{Y}_{rx}$, from the locus in that random breeding population is obtained by substituting $\bar{p}$ for p in (1). We get

$$\bar{Y}_{rx}=2u[\bar{p}+a\bar{p}(1-\bar{p})]. \qquad (12)$$

From (2), (3) and (12) by procedures followed in getting (9), (10) and (11) we obtain

$$\bar{Y}_{rx}=S_x-\frac{(S_x-\bar{X}_x)}{x} \qquad (13)$$

as given by Wright (1922). Now note that the divisor of $(S_x-\bar{X}_x)$ or $(S_{na}-\bar{X}_x)$ in (9), (10) and (11) is in each case equal to (2^x-1). It

seems likely that a general equation for rotations involving x lines or breeds can be written as follows:

$$R_x = S_x - \frac{S^1 - \overline{X}_x}{2^x - 1} \qquad (14)$$

where $S^1 = S_x$ when $x \leqslant 3$ and $S^1 < S_x$ when $x > 3$. Then

$$\left[S_x - \frac{S^1 - \overline{X}_x}{2^x - 1}\right] > \left[S_x - \frac{S_x - \overline{X}_x}{x}\right]$$

because $(2^x - 1) > x$ and because $S^1 \leqslant S_x$. It follows that if crossing of several breeds or lines followed by random mating offers a means for obtaining improved performance, as concluded by Wright, rotational cross-breeding offers a means of even greater improvement.

On the basis of equalities derived above, it is possible for a breeder to predict the best possible rotation for use with the specific lines, breeds or families available. The poorer performing rotations can be eliminated in advance of testing each possible rotation thus saving valuable time and expense.

Non-Validity of Assumptions

East (1936) advanced a theory for heterosis based on multiple alleles. Quite aside from East's proposal there seems every reason to believe that when several breeds are in question there is a good chance that more than two alleles are in the picture. While derivations are much simpler under the assumption of no multiple alleles, it can be shown that allowing multiple alleles does not change the equations obtained.

When there are interactions of non-allelic genes, the effects of the genes at one locus are not independent of genes at other loci. Thus, the relations among the various phenotypic means would be affected. The extent of the effects on these relations can not be indicated at present and would probably differ depending on the nature of epistasis present. While epistasis would change the various relations, it is by no means certain that it would change them very much. Although there is probably some epistasis, it is also not certain that the amount and kind present is such that prediction procedures based on its absence would suffer much as a consequence. The familiar method of predicting double-cross performance in corn, which is completely sound in theory only if no epistasis is assumed, has been successful and useful. In this connection, it should be noted that the mean of a double-cross (5) is the same as the average of four of the six possible single-cross means

(3) omitting the two parent single-crosses. This average of the four single-crosses was concluded by Jenkins (1934) in an empirical study to be the best predictor of the double-cross performance in corn and is the one currently used.

No assumptions were made regarding linkages because in the absence of interactions among non-allelic genes linkages do not affect the expected phenotypic means or prediction equations.

Summary and Conclusions

Basis for predicting the performance of rotation crosses from the performance of single-crosses and of the parent breeds or lines, and where the number of lines or breeds does not exceed four, were presented. Although these rest on various assumptions no epistasis is the only assumption that might seriously affect the results. The findings indicate that rotational breeding offers an even greater advantage to breeders than the crossing of several breeds or lines followed by random mating. These also enable the breeder to predict which breeds or lines and what order of rotation will give maximum performance in the rotational program.

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NEWS AND NOTES

Members are reminded that the 1956 annual meeting will be held at Hotel Sherman, Chicago, on November 23 and 24.

The North Atlantic Branch of the American Society of Animal Production met June 13, 1956 at Cornell University, Ithaca, New York. The regional officers elected were: President, G. W. Vander Noot, Rutgers University; Vice President, W. H. Riddell, University of Vermont; and Secretary-Treasurer, W. W. Green, University of Maryland.

The Public Health Service has announced that research grant applications for a one year period which do not exceed $2000 plus indirect costs will be accepted and processed on receipt, and are not subject to the usual deadlines for submission. All applications and requests for forms or information should be addressed to the Division of Research Grants, National Institutes of Health, Bethesda 14, Maryland.

Iowa State College has released a 16 mm black and white sound film entitled, "Probing for Profits". The film deals with selection of breeding stock to build a breed of meat type hogs. To order prints contact: Film Production Unit, Iowa State College, Ames, Iowa.

Harold H. Pierce, who completed his Ph.D. degree at the University of Illinois, is now Extension Specialist at the University of Kentucky.

Harold H. Cole, Chairman of the Department of Animal Husbandry, University of California, has been granted a Fulbright Fellowship and will spend a year at the Royal College of Agriculture and Veterinary Science, Copenhagen, Denmark, beginning July 1, 1956.

Roy C. Dawson, formerly Consultant on International Relations on the staff of the Administrator of the Agricultural Research Service, has been named Agricultural Officer in the North American regional office, Food and Agriculture Organization. He succeeds S. H. Work, who resigned last year to become Agricultural Attache to Chile. Dr. Dawson has returned from Rome where he spent 5 weeks in the headquarters office for briefing and orientation.

George K. Davis, Head of the Animal Nutrition Laboratory, University of Florida, received the American Chemical Society's Florida award for outstanding research in mineral metabolism of farm animals and the role of vitamin E in the prevention of muscular dystrophy.

R. H. Lush, Professor of Dairying, University of Tennessee College of Agriculture, and dairy husbandman of the experiment station, was granted a 2-year leave, effective January 4, to serve as pasture forage and livestock adviser to Brazil, under the International Cooperation Administration.

Richard F. Davis, formerly Assistant Professor of Dairy Husbandry, University of Maryland, has been appointed Head of that Department, succeeding Glenn H. Beck, who recently resigned to become Director of the Kansas Experiment Station.

Hugh D. Naumann, formerly assistant Professor of Animal Husbandry at Cornell

University, has joined the staff of the Animal Husbandry Department at the University of Missouri.

B. E. Sheffy resigned his position as Assistant Professor of Animal Husbandry at Cornell University to accept an appointment in the New York State Veterinary College at the same location.

James B. Fitch, Head of the Dairy Department of the University of Minnesota since 1935, retired on June 30.

E. F. Ferrin, Head of the Animal Husbandry Department, University of Minnesota, since 1949, retired from this position on June 30. L. E. Hanson was made Head of this Department July 1.

W. F. Brannon, formerly animal husbandman at the Range Experiment Station, Burns, Oregon, has been appointed Assistant Professor of Animal Husbandry at Cornell University.

Robert L. Cowan, associate professor in Animal Nutrition, Pennsylvania Agricultural Experiment Station, has been awarded a Fulbright fellowship for study and research in agronomy at the Massey Agricultural College, Palmerston, New Zealand. Dr. Cowan also has been invited to present a paper at the Seventh International Grassland Congress in New Zealand next November.

D. E. Ullrey is employed as Assistant Professor in the Animal Husbandry Department, Michigan State University, effective January 1, 1956.

Berl A. Koch is now Assistant Professor in the Animal Husbandry Department, Kansas State College.

Anton W. Sorenson has transferred from Mississippi State College to Texas A. and M. College where he is employed as assistant professor.

Floyd D. Carroll, Professor of Animal Husbandry, California Agricultural Experiment Station, is spending a year of sabbatical leave at the University of Ceylon, Colombo.

L. A. Holland, Assistant Professor, Animal Husbandry Department, Kansas State College, is on leave from his regular duties to complete resident work for an advanced degree in animal breeding.

J. H. Hopper has been appointed Assistant Professor in the Animal Husbandry Department, University of Nebraska.

Charles M. Martin, formerly associate animal husbandman, Alabama Polytechnic Institute, resigned his position March 31, 1956, to accept a position with the Quaker Oats Company, Memphis, Tennessee.

Moore J. Burns, associate animal nutritionist in the Animal Husbandry Department, Alabama Polytechnic Institute, has transferred to the School of Veterinary Medicine.

C. B. Safley, formerly assistant animal husbandman, University of Arizona, is now employed as an examiner of livestock loans by a bank in Tucson, Arizona.

Charles M. Thompson has resigned his position as assistant animal nutritionist at the Kentucky Agricultural Experiment Station and is now employed by the Beardstown Mills Co., Beardstown, Ill.

J. J. Norris, associate animal husbandman, New Mexico Agricultural Experiment Station, is serving as a member of the Technical Assistance team in Pakistan.

J. M. Griffith, assistant animal husbandman at the University of Tennessee, resigned from this position in October 1955 to enter the University of Tennessee Medical School.

E. E. Goodwin is now stationed at the Rice experiment station, a branch of the Louisiana Agricultural Experiment Station at Crowley. He was formerly assistant animal husbandman at the Washington State College, Pullman.

T. O. Meyer, formerly assistant animal husbandman at the Washington Agricultural Experiment Station, is now on the staff of the California State Polytechnic College, San Luis Obispo, California.

Frank H. Baker has been made head of the nutrition section of the Animal Husbandry Department, University of Kentucky. He was formerly assistant professor at Kansas State College.

Ralph L. Boulware, assistant animal husbandman at Mississippi State College, resigned from this position June 30, 1955. His present address is St. Francisville, La.

Frank S. Scott, Associate Animal Husbandman, and James E. Anderson, assistant Animal Husbandman, are recent additions to the Animal Husbandry staff at New Mexico A. and M. College.

G. E. Combs joined the staff of the Animal Husbandry Department of the University of Florida with the rank of assistant animal husbandman, effective September 1, 1955.

Recent additions to the Animal Husbandry staff of the University of Tennessee include Ira L. Dyer, Robert L. Saffle, J. H. Sanford, and Shelby O. Turner, all with the rank of assistant animal husbandman.

K. W. Scott is assistant animal husbandman at the University of Arkansas.

Solomon Bloom was appointed assistant animal nutritionist at the Puerto Rico agricultural experiment station, Rio Piedras, after completion of his Ph.D. degree in animal nutrition at Iowa State College.

D. C. England, formerly on the research staff of Hormel Institute, University of Minnesota, Austin, is assistant animal husbandman at Oregon State College.

Troy B. Patterson, associate animal husbandman, Mississippi State College, returned to his regular duties February 1, 1956, following leave for graduate study at Texas A. and M. College.

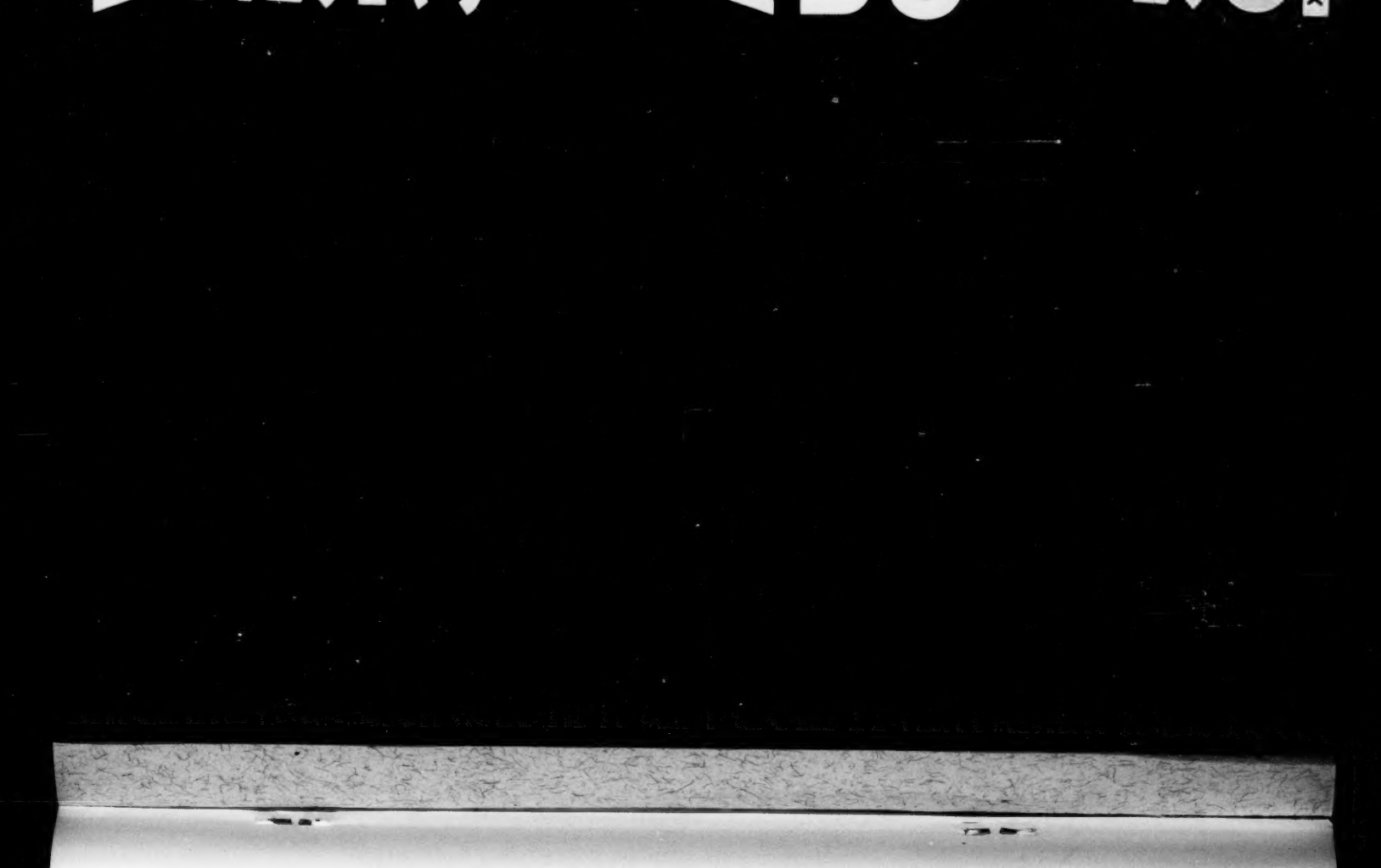
Earl Wiggins, formerly animal geneticist at the Western Sheep Breeding Laboratory, Dubois, Idaho, is now a member of the animal husbandry staff at the Alabama Polytechnic Institute.

E. H. Cobb, formerly instructor in animal husbandry at the Pennsylvania State University, is now at New Mexico A. and M. College.

C. W. Hickman, head emeritus, Department of Animal Husbandry, University of Idaho, died of a cerebral hemorrhage at his home May 2, 1956. Professor Hickman was one of the best known livestock experts in the West and during his long career at the University which began in 1915 his influence was widespread through his close contacts with purebred livestock breeders and experiment station bulletins authored by him. Hickman had been national secretary of the American Suffolk Sheep Society since 1935. He was the first president of the Western Section of the American Society of Animal Production. In 1952 he was honored by former students and associates with establishment of the Hickman Hall of Fame on the University campus.

John W. A. Brant has been appointed Professor Honorario at the Universidad de Guayaquil, Ecuador.

Publication has been announced of 16 original papers presented at a symposium on Reproduction and Infertility held at Michigan State University on June 27–29, 1955. The paper bound book, including more than 100 illustrations is available at the Michigan State University Bulletin Room, 10 Ag. Hall, East Lansing at $3.00 per copy.



INFORMATION FOR CONTRIBUTORS

1. Papers may be submitted reporting work whose ultimate objective is clearly the solution of a livestock production problem and whose contents should be of interest particularly to those dealing with livestock production problems. Review papers on subjects of general interest will also be published at intervals, and will be prepared on invitation by the Editorial Board.

2. All papers will be subject to critical review by the Editorial Board, or others designated by the Editor. Papers needing revision will be returned to authors and should be revised and returned promptly. Papers not suitable for publication will be returned to authors with a statement of reasons for not accepting them.

3. Papers submitted should be based on new and adequate information. The following are guides to style and form:

   (a) Manuscripts must be typed, doubled-spaced, and the ribbon copy submitted.

   (b) Pages must be numbered. The lines of text must be numbered in the left margin, beginning with one at the top of each page. This does not apply to tabular material.

   (c) Tables should be as few and as simple as is feasible for presentation of the essential data.

   (d) Legend for each figure should be typed on a separate sheet. Photographs should be carefully prepared and labeled. Magnifications of photomicrographs should be indicated on legends. Charts should be prepared in India ink. Typed material on charts is not acceptable. Material that will not reproduce satisfactorily will be returned for revision. For suggestions on preparing illustrative material see the "Style Brief" published by the Wistar Institute Press, Philadelphia. If in doubt, consult the Editor before putting material in finished form.

   (e) The introduction should consist only of a paragraph indicating very briefly the nature of the question asked and the reason for asking it. Reference to relevant literature should be made later in the discussion of the results. Concise presentation of data is desired and there should be evidence of statistical examination wherever obviously useful in the interpretation. Unsupported hypotheses should be avoided. The organization of a manuscript may vary with the nature of the material, but all manuscripts should contain a clear statement of application of the results or their relation to some problem of the livestock industry. Each paper should end with a brief summary in the form of an abstract containing the most pertinent data in the briefest possible form.

   (f) Literature citations must be listed in alphabetical order and should be referred to in the text by author and date, i.e., Castle (1924), or (Castle, 1924). Citations may be referred to by number in review articles where the number of citations is too great to permit convenient use of the above form. "Literature cited" lists should be typed in a style used in a current issue of the JOURNAL.

4. Manuscripts will be edited in the order received, and accepted papers will be published as nearly in this order as feasible.

5. There will be a charge for making engravings in excess of one page per paper and of printing tables in excess of two pages per paper. The author will be asked when his manuscript is accepted to indicate the institution, agency or individual that will assume responsibility for the charges and for the reprints ordered at that time.

6. Authors will receive galley proof of articles together with a form for supplying an abstract for "Biological Abstracts." *Corrected proof and abstract should be mailed to the Editor within three days after they are received. Failure to do this may result in delay of publication until the next issue.*

7. One author of each manuscript should be a member of the Society. Papers by non-members can be published only after approval by the Executive Committee.

8. A "News and Notes" section will be published in each issue, including Society announcements, changes in positions and other items of professional interest to members. All such items should be sent promptly to the Editor.

9. Abstracts of papers to be presented at the annual meetings of the Society will be published in the November issue. Such abstracts must not exceed 250 words in length, should be typed (double spaced) and the ribbon copy submitted, the lines on the page should be numbered, in the left margin, from top to bottom, and must be in the hands of the Secretary of the Society by August 15, preceding the meeting. These abstracts must be summaries of results and conclusions.

10. Presentation of a paper at the annual meeting does not exclude it from publication in complete form in the JOURNAL. Such papers may be submitted to the Editor and will be given equal consideration with others submitted.

11. All manuscripts and correspondence concerning them should be addressed to the Editor: Dr. J. K. Loosli, Department of Animal Husbandry, Cornell University, Ithaca, New York, or to the publishers: Boyd Printing Company, 372–374 Broadway, Albany 7, New York.

12. All correspondence concerning subscriptions to the JOURNAL OF ANIMAL SCIENCE and other business matters should be addressed to the Business Manager, Dr. W. M. Beeson, Department of Animal Husbandry, Purdue University, Lafayette, Ind., or to the publishers, Boyd Printing Company, 372–374 Broadway, Albany 7, New York.